

COMBAT RATION NETWORK FOR TECHNOLOGY IMPLEMENTATION

Non Destructive Seal Testing Polymeric Tray

Final Technical Report STP#2016

Results and Accomplishments (April 2002 – November 2004)

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Abstract:

Seal strength measurements and analyses of flexible and semi-rigid containers are usually done by destructive methods. Most of the non-destructive testing methods focus on leak detection and seal integrity rather than quantification of the seal strength. At present, there is no method capable of quantifying or assessing the seal (e.g. tack, creep) strength non-destructively.

Short Term Project #2016 was given the task to develop a prototype non-destructive (ND) test system for the polymeric half steam table tray. It must expose the seal to forces that open the seal when it is a non-fusion seal. If successful, the ND tester would replace the traditional internal pressure test method.

The ND tester is based on a static compression force that reduces the volume of the tray, increasing the pressure within the tray. The design of the top compression plates is such that a peel force is created on the seal during this compression cycle. Based on seal strength data of fusion and non-fusion seals, a test protocol was developed and validated that rejects non-fusion seals, while accepting fusion seals. Compared to the traditional internal pressure test protocol, a higher seal quality will be required to pass the ND tester.

The ND test methodology was also used to evaluate the effects of seal anomalies. Based on the outcome of the ND test, it was determined that trays with visual defects can be classified as critical, major, minor and non score-able defects.

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1 Results and Accomplishments

1.1 Introduction and Background

Seal strength measurements and analyses of flexible and semi-rigid containers are usually done by destructive methods. Most of the non-destructive testing methods focus on leak detection and seal integrity, rather than quantification of the seal strength. At present, there is no method capable of quantifying or assessing the seal (e.g. tack, creep) strength non-destructively.

Short Term Project #2016 was given the task to develop a prototype non-destructive (ND) test system for the polymeric half steam table tray. It must expose the seal to forces that open the seal when it is a non-fusion seal. If successful, the ND tester would replace the traditional internal pressure test method.

The currently used internal pressure test protocol confines the tray between two plates that are 1/16" to 1/8" taller than the tray and air is injected into the tray to generate 20 psig internal pressure that is held for 30 seconds. The seal is inspected after the test to determine final seal width and seal creep. The internal pressure test has shown that seals of marginal quality, containing sections of non fusion seals, have passed.

1.2 Objectives

The original objective of the project was to design and fabricate a prototype test system and develop and validate test protocols for this non-destructive seal tester capable of evaluating overall seal strength, tack seals and seal creep.

During the course of this project, the scope was expanded to evaluate the seal strength of trays with visual seal defects. These visual defects should be sorted out in a 100% in-process inspection step but due to the inefficiency of this inspection process, a percentage remains in the finished product lot. If one or more visual defects are found during the finished product inspection step, the lot needs to be re-worked, depending on the classification of the defect. Currently the classification as to the effect on the seal strength is arbitrary.

1.3 Results and Conclusions

A non-destructive compression tester (ND Tester) was developed for half steam table polymeric trays. The ND tester is based on a static compression force that reduces the volume of the tray, increasing the pressure within the tray. The design of the top compression plates is such that a peel force is created on the seal during this compression cycle. Based on seal strength data of fusion and non-fusion seals, a test protocol was developed and validated that rejects non-fusion seals, while accepting fusion seals. Compared to the traditional internal pressure test protocol, a higher seal quality will be required to pass the ND tester, which was an objective of this project. Trays with various retorted products were tested successfully without product damage. Solid products such as baked goods are not suited for this test, as they have inadequate hydraulic movement and result in product damage. Seal strength testing performed on trays before and after the compression test demonstrated a statistically insignificant weakening of the seal strength for the lid stock that was available at the CORANET Demo Facility.

The ND test methodology was also used to evaluate the effects of seal anomalies in trays supplied by the Industry. It was determined that, while the seal anomaly might indicate a problem with the seal, the weakest part of the seal is not necessarily in the spot of the anomaly and weak seals do not necessarily cause visual defects. Trays with visual defects can be evaluated in the

ND tester to determine the severity of the defect and to classify the defect appropriately as critical, major, minor and non-score-able.

2 Program Management

The project was awarded on September 26, 2003, under SPO103-02-D-0024, delivery order 0008 with a partial obligation (\$56,478.30) of the total requested amount of \$152,636.00. Performance period for this delivery order was set at 12 months from October 1, 2003 through September 31, 2004. The contract was awarded to design and fabricate a prototype test system and develop/validate test protocols for a non-destructive seal tester capable of evaluating polymeric tray seals for overall seal strength, tack seals and seal creep.

The following modifications were issued:

Jan 20, 2004	0008/01	Add incremental funding to increase total obligation from \$56,478.30 to \$152,636.00
Sep 30, 2004	0008/02	No cost extension from September 30, 2004 to April 30, 2005
Nov 5, 2004	0008/03	Obligation of additional funding, increasing total obligation to \$200,260.00
Apr 18, 2005	0008/04	No cost extension until May 31, 2005
May 27, 2005	0008/05	No cost extension until July 30, 2005
Jul 28, 2005	0008/06	No cost extension until December 31, 2005
Sep 20, 2005	0008/07	Increase in obligation from \$200,260.00 to \$216,378.00
Dec 19, 2005	0008/08	No cost extension of the performance period until June 30, 2006
June 30, 2006	0008/09	No cost extension of performance period until August 30, 2006
July 31, 2006	0008/10	Extension until October 30, 2006 and increase of obligation from \$216,378.00 to \$223,081.00

3 Short Term Project Activities

3.1 Evaluation Competing Technologies

A comprehensive literature search was performed for destructive and non-destructive test methodologies, including an industry survey of existing systems that could perform non-destructive seal strength measurements. The full report of this task is available as Technical Working Paper #219: "Non Destructive Seal Testing, Evaluation Competing Technologies".

Most of the "commercial off the shelf" systems are designed to detect seal integrity issues, such as seal contamination, cuts and holes. A few systems create a force on the seal, by applying a vacuum, causing weak seals to fail. These forces are, however, a function of the residual gas level inside the tray and the forces are much lower than those generated by the destructive internal pressure test. It was determined that only the compression test with a static load would have the potential to generate the required forces on the seal. While the test is identified during the literature search, no vendor could be found that markets such test apparatus.

3.2 Engineering and Design Specifications

Mr. Bruins from the CAFT-FMT Facility and Dr. Basily from the Rutgers Industrial Engineering Department developed engineering and design specifications for the static compression tester. The following specification descriptions are included in the final prototype system.

- Tester shall enclose the tray around the perimeter to eliminate "bowing out" of the tray and produce unintended stresses in the film. The tray holder shall be sized to a retorted tray which is slightly smaller than the original tray.
- The tester shall use pneumatics to control the movement of the compression plates

- The tester shall have a top plate that is 1" inside the flange of the tray allowing the lid stock to bulge up and create a force on the seal. This top plate shall be locked in place at the flange height.
- The tester shall have a bottom plate that is used to compress the tray against the top plate. The shape of the bottom plate shall be sized to the oval indentation in the bottom of the tray to minimize permanent deformation of the tray. The compression force on the tray shall be controlled by the air pressure in the bottom piston.
- The bottom plate shall not start the compression cycle unless the top plate is in position.
- The bottom compression plate shall be attached to a displacement sensor that monitors the position of the piston.
- The piston that controls the movement of the bottom plate shall have a permanent back pressure on the downward stroke and a fast dump valve on the upward stroke. This shall facilitate the quick release of the compression force when a tray seal fails. Also, this shall cause a gradual increase in the compression force at the beginning of the cycle as the air in the top side of the piston is compressed and slowly leaks back.
- All air pressure on the pistons shall be removed when the door is opened or when an emergency button is activated.
- The chamber around the compression plates shall be made of quick removable panels for easy cleaning of the tester, in case of product spillage.
- The bottom compression plate and piston shall be sealed off from the test chamber with a membrane to prevent food product contamination of this difficult to clean area.
- The electronics shall be located in a Nema 4 enclosure to facilitate wash down of the equipment
- The maximum stroke of the compression plate shall be adjustable to mechanically limit the compression stroke and minimize the spillage of product, if a seal failure occurs
- The position of the top plate shall be adjustable to position the top compression plate in relation to the tray flange.
- All parts of the test chamber shall be either aluminum or stainless steel.
- The tray holder shall provide clearance so that the tray can be tested while double bagged.
- The operation of the tester shall be controlled via a PC-USB interface
- The control software shall be written in Visual Basic

3.3 Fabrication Prototype System

The prototype compression tester was designed and manufactured by Dr. Basily and assisted by Hesham Fahmy, a graduate student from the Rutgers Industrial Engineering Department. The two main components of the tester are two air pistons (6" diameter) that create the compression force. With an 80 psig supply air pressure, each piston can generate a maximum of 2,262 lbf.

Several upgrades and changes were made as testing proceeded. While initial design requirements stipulated a vacuum pull on the tray, it was found that this created too much stress on the container which was evident by the discoloration of the tray. Also, the initial design had a clamp down ring on the flange to hold the tray in place during the test cycle and to assure a good vacuum seal under the tray. After initial testing, it was determined that a correct placement of the top plate was sufficient to maintain the position of the tray in relation to the tray holder. Both vacuum requirement and the clamp-down-ring were eliminated.

A key component of the tester is the shape of the top plate. Initial design caused excessive stresses in the film at the corners of the plate, causing permanent deformation of the film. The final shape eliminated this, making the test non-destructive.

Seal burst during the compression cycle will result in product spillage from the container. Several upgrades were implemented to facilitate easier cleaning. The latest design, in combination with double bagging of the tray, virtually eliminates cleanup requirements.

Drawings of the tester are included in the User and Maintenance Manual (TWP #222). The cost of the tester is estimated at \$20,000/unit.

3.4 *Developing System Control Software*

The control software was written in Visual Basic.Net by Tom Blyskal, a student at the Department of Industrial Engineering. Initial software included modules to evaluate various force patterns such as static, cyclic, step cyclic, etc. The more complicated force patterns did not make significant differences from the simplest force pattern (static compression) in detecting weak seals. Fatigue and stress cracking of the film was a concern in the cyclic testing, but might be of value when testing a tray for cyclic fatigue. The final version of the software was re-written to this simplest model. The program includes features to detect a sudden drop in pressure and/or movement of the compression piston to terminate the test. These are indicators of a leaking or failing container. However, due to the explosive nature of most seal failures, the software and subsystem response time could not prevent spillage of the product. Thus mechanical upgrades were made to the tester to minimize the effects of spillage.

The software logic of the tester is:

- Push "Start" button, to start the test cycle
- Lower bottom plate to accept new tray
- Insert tray
- Push "Continue" button
- Lower upper compression plate and hold in position (80 psig)
- Raise bottom compression plate (60 psig) with 10 psig on the downward stroke for a net compression force of about 1429 lbf
- Maintain compression force for 60 seconds
- Lower bottom plate
- Raise top plate
- Raise bottom plate to eject tray from tray holder
- Remove tray and inspect seal for minimum remaining seal width
- Exceptions: If the tester detects a failed tray, do not eject tray automatically but allow operator to clean area so that no product spills into the tray holder
- Exceptions: If the tester detects that the operator activated the "Emergency Stop" button or if the door is opened during the test, drop pressure from all pistons for safety

The run time files for this software are available upon request.

3.5 *Developing Test and Operating Conditions*

Extensive testing was done on trays produced at the CORANET Demo Site with variable seal conditions. The results of this testing is summarized in Technical Working Paper #220 "Non Destructive Seal Tester, Test Data". Conditions were developed that separated two populations of seals. The first population had a high incidence of tacky seals, while the second population had a low incidence of tacky seals. A 1429 lbf compression force on the tray for 60 sec. resulted in a high fail rate on the first group and a low fail rate on the second group. This force is about 40% lower than the force that is required to fail a "well-sealed" tray.

An operating manual was written for the tester and issued as Technical Working Paper #222 "User Manual, Non Destructive Seal Tester for Polymeric Trays". While the prototype ND tester requires a PC to operate the unit, the same actions can be accomplished with a solid state relay control system.

3.6 Validation Testing

To validate the tester and the test protocol, trays were obtained from Producers and Government Depot. The validation testing consisted of two parts. In the first part, the tester was validated as a replacement of the current IP tester. In the second part of the validation test, the tester was used to evaluate the severity of visual defects. Protocols were written for both tests; including a proposed accept/reject criteria (see Appendix 4.5).

3.6.1 Validating Non-Destructive Static Pressure Test

Trays were obtained from Government Depot for this validation test. The description of the test and the results are documented in TWP#221. Trays were tested by both the IP test and the ND test. Results of these tests clearly demonstrated that the ND test rejected more trays than the IP test, but that the rejected trays had non fusion sections.

The conclusions from this test were:

- **The ND test fails seals that pass the IP test and thus a higher seal quality standard is required to pass the ND test**
- **Seal width of trays with good quality seals are statistically similar after the IP and after the ND test. Seal width of trays with marginal quality seals are significantly less after the ND test than after the IP test.**
- **The ND test will cause between 0.0 to 0.01" additional seal creep on good quality seals after the initial IP test condition. The additional seal creep is less than the variation in seal width typically seen in a population of well sealed trays.**

3.6.2 Quantification of Visual Defects

Visual defects are sorted out in a 100% in-process inspection step, but can still be found during the finished product lot inspected when 200 trays are evaluated. If one or more visual defects are found, the lot might need to be re-worked. The ND test methodology is being proposed as a tool to evaluate these visual defects and determine if the visual defect has a negative impact on the performance of the tray. If it can be determined that the tray withstands the ND test protocol and the remaining seal is more than 1/16" wide, the visual defects had no significant effect on the performance of the tray and the defect is purely aesthetic.

To validate this concept, 62 trays with potential seal problems were received from one of the producers. The seals were evaluated for seal defects. The results were:

- 32 trays had visual defects, such as impressions and/or seal wrinkles. All were tested in the ND tester for seal creep. The results were:
 - 28 trays had non scorable defects, seal width > 1/8" (87.5%)
 - 3 minor: seal width >1/16, <1/8" (9.4%)
 - 1 critical: seal width <1/16" (3.1%)

Note: seal creep did not occur in area were visual defect was observed.

- 30 trays with no visual defects were tested in the ND tester and evaluated for seal creep. The results were:
 - 28 passed
 - 2 failed (seal burst)

More detailed results of the test are documented in Technical Working Paper #220, section 3.7.

The conclusion of this validation test was:

While visual defects in the seal might be an indication that seal contamination had occurred, the results did not indicate that the particular area in which the defect is located, is any weaker than the adjacent areas. Nor, could the conclusion be made that weak and/or contaminated seals always result in visual indicator. Therefore, it appears that the ND tester can be a useful tool in evaluating the true quality of the seal and the severity of the visual defect and can prevent a majority of reworks due to visual defects.

It was further recommended that the ND tester be used by the producer to study the effects of seal contamination to validate that the cleaning procedures are effective. While seal contamination should be avoided during the filling process, it does occur and proper cleaning procedures to remove the effects of the contamination must be in place. Also, seal conditions should be such that even when seal contaminant remains, it should not lead to marginal quality seals.

3.7 Cost Benefit Analysis

USDA first inspection data indicates that an average of 469 lots/year was produced during the period 2001-2004.

Each lot is inspected in-process by the producer to assure hermetically sealed containers. This inspection is typically done every two hours for every seal head and after each major shutdown. Assume that a total of 12 trays are tested for every lot at a cost of \$5/tray.

Savings: $469 \times 12 \times \$5 = \$28,140$

Each tray is inspected after sealing for seal defects. Assume that 2% of the trays are being "sorted out" due to visual defects at a cost of \$5/tray and that the average lot size is 5,000 trays/lot.

Cost: $469 \times 2\% \times 5,000 \times \$5 = \$234,500$

Assume that the ND tester can reduce this by 25% by redefining the severity of defects.

Savings: \$ 58,625 savings

A finished product lot is inspected first by the company based on a statistical sample (Inspection Level S1. For lots that range from 501 containers to 35,000 containers, the sample size is 5). Assume that the cost of the tray at this point is \$15/tray.

Savings: $469 \times 5 \times \$15 = \$35,175$

After the lot has passed the producers inspection, the lot is offered to the Government for acceptance. Again, the same sampling plan is used and for most lots, the sample size will be 5.

Savings: $469 \times 5 \times \$15 = \$35,175$

USDA data indicates that in 2004, 5% of the lots were rejected based on entrapped matter. Assume that the cost of rework is \$2,000/lot and that the lot size is 5,000 trays/lot. Further assume that 1% of the trays are rejected during rework.

Cost: $(\$2,000 + 1\% \times 5,000 \times \$15) \times (5\% \times 469) = \$2,750 \times 23 = \$63,250$

Assume that the ND tester can prevent 80% of the lots from being reworked.

Savings $80\% \times \$63,250 = \$50,600$

Total Savings: \$207,715

It is estimated that the cost of the ND tester will be approximately \$20,000/unit. If we assume that two producers have the capability to produce polymeric trays and that each of them has to buy one unit, a total investment of \$40,000 has to be made. Payback will be accomplished in less than 3 months.

3.8 Demonstrations

The first IP was held on May 6, 2005, at which time the tester was demonstrated for the first time as a compression tester. The presentation overheads are include in the Appendix 4.6

A second and final IPR meeting was held on May 31, 2006. The project progress was reviewed, including the validation data and a demonstration of the tester. The overheads for this presentation are included in Appendix 4.7

4 Appendix:

**4.1 TWP#219: Non Destructive Seal testing, Evaluation
Competing Technologies**

4.2 TWP#220: Non Destructive Seal tester, Test Data

**4.3 TWP#221: Validation Test Report, Non Destructive Seal
Tester versus Internal Pressure Test**

**4.4 TWP#222: User Manual, Non Destructive Seal Testers for
Polymeric Trays**

4.5 Non-Destruct Protocol, version 1.3

4.6 IPR #1

4.7 IPR #2

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**Non Destructive Seal Testing
Evaluation Competing Technologies
Technical Working Paper (TWP) #219**

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1 Introduction

Semi-rigid containers are either closed with a conventional double seam metal lid (bowls) or heat sealed with a flexible lid stock. To ensure that the closure is hermetic and will withstand normal abuse, quality control measurements need to be performed to assure a certain standard. Containers can be examined non-destructively via visual inspection to ensure that no visual abnormalities in the seal exist and via destructive measures to quantify the actual strength of the seal. The material loss due to the destructive test can become significant as the size of the container increases. The development of a non-destructive test to assure minimum seal strength can lead to significant cost savings. The goal of this project is to develop a non-destructive seal tester for the Half Steam Table Tray that is being used by the Department of Defense in their combat ration feeding program.

Preliminary tests were performed on Polymeric Trays to evaluate the concept of pressurizing a filled polymeric tray by applying external forces on it. This reduces the volume of the tray and builds up pressure inside the tray and stresses the seal. The concept seems to be feasible and promising, but other methods might exist and be even more effective. Hence, the need exists for a review of the literature and available competing technologies prior to engineering a system that is based on the above mentioned principle.

2 Objective

The objective of the task is to search and evaluate competing technologies, by literature search, consultations, examinations, demonstrations, and comprehensive documentation to support the technology selected.

This report summarizes the result of this literature search and presents a comprehensive survey of the current methodologies used for seal testing of retortable trays. In seal testing, we need to distinguish between two different characteristics: seal quality and seal strength. In seal quality, one looks at the width of the seal and determines if any anomalies exist within the seal. In seal strength, one determines if the seal is strong enough to withstand a certain abuse force before opening/failing. While there might be some correlation between a good looking seal and a strong seal, there is no absolute assurance that there is a connection. A good looking seal can fail the seal strength test and a bad looking seal can be strong enough to withstand the abuse force.

We review the various tests and classified them into two types: Seal Integrity and Seal Strength. The following sections present these testing methods accordingly.

3 Literature Survey

3.1 *Package Integrity*

Current Package Integrity test methods include:

- Pressure Differential Methods
- Visual Inspection
- Machine Vision
- Bubble Test
- Biotest
- Electrolytic Test
- Dye Penetration Test
- Various Scanning Techniques

A detailed comparison of various non-destructive analytical leak-detection techniques was reported by Harper et al. (1995).

3.1.1 Pressure Differential Methods

Pressure differential methods have been used to test cups, trays, and pouches for leak detection. Packages to be tested are inserted into a specifically designed chamber with a seal around them and then the test is conducted. When there is a pressure differential across the wall of a package, a possible leak will cause a test gas such as air or nitrogen to flow in or out of the package. An observed gas flow is an indication of a leak. Two common methods are used for detecting gas flow. The first method is based on measuring pressure changes using a very sensitive pressure sensor. The second method is based on measuring changes in the deflections of the package wall caused by the gas flow using a proximity sensor.

Pressure differential techniques are classified into the vacuum method and the external pressure method. In the vacuum method, a package is placed inside an enclosed chamber where a vacuum is drawn to create a pressure differential across the package wall. Gas or liquid will flow out of the package because the pressure inside the package (at about 1 atmosphere) is higher than the pressure in the vacuum chamber. The vacuum method works well for packages containing dry product or for packages having well-defined headspaces. It can be used for detecting gross leaks ($\geq 100\mu\text{m}$) and for testing seal strength. However, it is not suitable for detecting smaller leaks, especially when the package contains a wet product. Yam (1995) stated that there are at least four problems with the vacuum method: (1) a certain amount in residual gas must exist in the package; (2) since the pressure differential ΔP is limited to about 1 atmosphere, the gas flow rate is usually too small to be detected rapidly; (3) the residual gas may be dissolved in the liquid food, which severely limits the mobility of the residual gas; and (4) any moisture inside the package may plug up leaks, making detection impossible.

In the external pressure method, the external pressure driving force causes the test gas to flow from the outside to the inside of the package. Again, the pressure inside the package is about 1 atmosphere, but the pressure outside the package could be much higher (7 atmospheres or higher). Compared to the vacuum method, this method does not require residual gas to be present in the package, requires shorter test time, and can detect smaller leaks. The sensitivity of pressure differential methods varies widely and depends on the magnitude of pressure differential, type of gas, time allowed for testing, shape and size of package, amount of residual gas, etc.

In a study by Yam (1995), meals-ready-to-eat (MRE) pouches formed using horizontal-form-fill seal (HFFS) equipment were inspected for leaks and weak seals on-line non-destructively. According to Yam (1995), the system was capable of detecting $50\mu\text{m}$ diameter channel leaks in filled pouches within a few seconds.

The integrity of MRE pouches was inspected using a new pressure (vacuum) differential technique developed by Ayhan et al. (2001). The technique proved to be effective, although, short-sealed non-vacuum packed pound cake pouches failed during subsequent leak testing.

3.1.2 Visual Inspection

Visual Inspection is the simplest of non-destructive package integrity tests that can be applied to almost all types of packages. Visual testing, typically involves inspecting the seals for the absence of voids, wrinkles or pleats. It also checks for seal alignment, product contaminated seals and delamination of packaging materials. Visual inspection is, however, time consuming, expensive and its monotonous nature induces operator fatigue.

3.1.3 Machine Vision Imaging

Machine Vision is designed to eliminate visual inspection of packages. The objective is to detect holes in hermetic packages by computer evaluation of images with previously defined patterns of acceptance. Packages are positioned before a camera to present a consistent pattern. The video image obtained is

digitized. Both grayscale and color density may be evaluated. The computer compares coded patterns with acceptable patterns stored in memory. Some systems evaluate one image at a time. Others use parallel computers to evaluate different segments of the video image in less time. Patterns that do not match the acceptance criteria result in rejection of the package from the production line

3.1.4 Bubble Test:

Bubble emission testing involves the creation of a pressure differential across the package with air (or some other gas) on the high pressure side (inside the package) and a liquid bath on the low pressure side (outside the package). Air or gas flow through leaks will result in the formation of bubbles outside the package. The pressure differential can be created by either pressurizing the package or by drawing a vacuum in the immersion tank/vessel. The disadvantages of bubble test are its low sensitivity and the tendency of leaks to get clogged by viscous food materials during testing.

3.1.5 Dye Penetration Test:

The dye test is used to locate leaks in packages or to demonstrate that no leaks exist. The container is first cut open and the content removed. The dye is then squirted along the inside of the seal with a syringe. After drying for 2 hours, the outside of the container seal is observed with a UV light to detect if the dye had penetrated through the seal. The dye test has been reported by Gilchrist et al. (1989) to detect leaks down to 20 μ m in diameter.

3.1.6 Biotest:

The objective of biotesting is to detect the presence of holes in hermetic packages by placing them in an agitated solution of fermentation bacteria in water for an extended period of time. It is reported to have sensitivity similar to that of the dye test, but with more precision (Gilchrist et al., 1989). Even if biotests are the most stringent testing methods, package integrity should not be assessed only on their results (Garret 1987).

3.1.7 Electrolytic Test:

Plastic packages generally do not conduct a flow of low-voltage electricity unless a hole is present. If an electric current can be measured, one can use a dye solution to identify the presence of a hole. This method may be used with packages containing metal, so long as the metal is coated with a polymer, which forms a barrier to electrical current. Very small holes may be located and their relative size determined using micro-ampereage. The smallest hole located using electricity was 1micron (μ m) in diameter and verified using transmitted light and a 1000-power microscope (Arndt et al., 1995).

3.1.8 Scanning Laser Acoustic Microscopy (SLAM):

A study was conducted by Safvi et al. (1997) to detect packaging defects using scanning laser acoustic microscopy (SLAM) operating at 100 MHz. The results indicate that the SLAM technology can readily detect channel defects as small as 10 μ m. It can detect defects in either clear or opaque pouches, and is capable of detecting defects containing solids, liquids, or gases.

3.1.9 Ultrasonic Imaging

Raum et al. (1998) introduced a new imaging technique called backscattered amplitude integral (BAI). The results show that the new BAI-mode imaging has the ability for sub wavelength detection of channel, e.g., detection of a 10 μ m diameter channel defect at a center frequency of 13.1 MHz. Ozguler et al. (1999) showed that there is a direct relationship between the defect size and Δ BAI value, and that different defect types and packaging materials have a significant impact on the Δ BAI value.

3.1.10 Infrared Imaging

The objective of Infrared Imaging is to observe differences in the absorbance and transmittance of heat energy (infrared light) in a package or seal. Infrared light may be absorbed, transmitted, and emitted by a package or a seal. Differences between these parameters provide a means for visual interpretation when

sensed automatically and enhanced for visibility. Infrared Imaging is very sensitive to environmental conditions and requires temperature control. Infrared imaging is most appropriate for monitoring seals as they are being heat sealed.

3.1.11 Infrared Laser / Fiber Optic Array

Infrared Laser measures the transmittance of a beam of infrared light through a transparent object. The fiber optic array does the same thing but uses the visible light spectrum. Only the infrared laser was able to identify a defect.

3.1.12 X-rays

X-ray systems have, so far, not been able to demonstrate the ability to find an unfilled leak with any useful resolution due to the lack of differential in density between a whole seal and two unsealed, but adjacent pieces of material (Morris et al., 1998). X-rays are able to detect a 1 μ m drop of water in either opaque or clear pouches, but are unable to detect 1 μ m channel leak because x-ray cannot detect voids unless there is something in them (Blakistone and Harper, 1995).

3.1.13 Eddy Current

An eddy current probe has been routinely used to detect breaks in the coating of pipes by changes in the transmittance of the electrical current. Although this probe does not work well for clear laminate pouches, it can detect defects in foil laminate pouches such as 'Meals Ready to Eat' pouches used by the military.

3.1.14 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging is capable of producing two- and three-dimensional images using magnetic fields and radio waves. MRI does not detect voids. If there is no water in the defect, there is no useful signal from which to construct an image.

3.2 Seal Strength

The currently available testing methods for seal strength can be grouped on the basis of their operating principles as follows:

- Inflation Testing
- Tensile Testing
- Compression Testing

3.2.1 Inflation Seal Strength Test:

There are several tests that inflate the container to determine the seal strength of the container. We can distinguish between the Burst Test, the Creep Test and the Creep to Fail Test. These tests can either be unconstrained or constrained between two fixed plates. Each of these methods will be briefly discussed.

3.2.1.1 Burst Test

The burst test is a method in which a whole package is inflated at a uniform rate, until it ruptures. It measures the peak pressure at rupture in order to determine seal strength and is the most commonly used seal-strength test. The burst test is a good overall test for seal strength, because it stresses the package uniformly in all directions and identifies the location of the weakest point and the pressure at which it fails. The results of burst pressure can, however, be affected by the package geometry and the rate of inflation.

3.2.1.2 Creep Test

The creep test inflates a package to a constant pressure and holds the pressure for a fixed time or until rupture occurs. After the test time has expired, the air is released from the package and the seal is inspected for creep. If the package bursts before this pressure is attained, the package fails. If the seal creep is more than specified upon inspection of the seal, the package fails as well. Shortcomings of the creep test include

the need to visually examine the seal at the end of the test to declare the amount of seal peel for process control. The lack of a variable statistic upon which to perform process control analysis is an other short coming.

3.2.1.3 Creep to Fail Test

The Creep to Fail (CTF) test is a variation of the creep test that addresses the data interpretation weaknesses of that test. In the CTF test, pressure on inflated packages is held until the seal actually fails, yielding an end-point value (a variable statistic) and time to failure and pinpointing the area of greatest weakness in the seal (ASTM F1140 method b2). Time to failure can then be used in SPC or SQC methods.

The inflation seal-strength tests (burst and creep) are discussed in ASTM standard method F 1140.3 This method describes the apparatus and process used to automatically inflate a whole package and capture the peak rupture pressure (the burst pressure) or measure the hold pressure (creep pressure) over a defined time period. The measuring equipment is used along with either a clamp to seal an open-ended pouch (an open-package fixture) or a device for penetration of a completely closed package.

3.2.2 Tensile Test

Tensile seal-strength test is a method to define the strength of the seal. The test uses a defined-width sample of a package perimeter seal. A moving jaw pulls the sample apart at a constant speed, while measuring the resistance force during the seal separation. The peak force that is required to accomplish this separation is typically recorded. If the force is below a previously designated range, the package is considered to lack adequate seal strength. The disadvantage of tensile testing is that it will not detect weak spots or stress points in other untested areas of the seal. The tensile test is, therefore, used for the surveillance of material stability and also to spot-check equipment operations and sealing conditions.

3.2.3 Compression Test

A compression test is similar to the internal pressure test in which the internal pressure is created by applying pressure to the package sidewalls. The package volume will decrease and the internal pressure created will strain the seal of the package. If the package is properly sealed, no headspace gases or product will escape. This test method will only work if the product is capable of transmitting the hydraulic pressures to the seal. Three different procedures were recognized by Arndt (2001) and are discussed in the following sections in more detail.

3.2.3.1 Static Method

In this method, a sealed package is placed on a flat surface and flat-surfaced weight is placed on top of the package. The effect of weight on integrity of the package is observed over time. This test method was discussed by Lampi (1976) as a potential seal strength test for MRE pouches. A similar test may be performed by applying a constant weight to a package moving on a conveyor belt. The speed of the moving belt determines the time of compression.

3.2.3.2 Dynamic Method

A constant increasing compression force is applied in the dynamic method. The maximum force required to cause failure of the package is measured. This test method is, therefore, destructive.

3.2.3.3 Squeeze Method

In this test method, manual kneading action is applied to force the product against interior seal surface. All seal areas are examined for evidence of product leakage or delamination. The sealing surface must be smooth, parallel, and free of wrinkles... Packages that exhibit delamination of the outer ply on seal area, but not at product edge should be tested further by manually flexing the suspect area 10 times and examining all seal areas for leakage or short-width (Canned Foods, Principles of Thermal Process Control, Acidification and Container Closure Evaluation 1995, sixth edition).

3.2.4 Testing Protocols

The American Society for Testing and Materials (ASTM) and the Department of Defense have several test protocols for Package Integrity, as outlined below.

3.2.4.1 ASTM F 88

The American Society for Testing and Materials (ASTM) test method for the tension test and is designated as ASTM F 88, "Standard Test Method for Seal Strength for Flexible Barrier Materials". This method is designed using a tensile testing machine to measure the force required to separate the seal of a 1 inch wide sealed sample. The rate of separation is usually fixed at 12 inches/min., with output measurement in pounds of force. The value chosen from a typical force plot can be peak value, average value, or force deformation. Though the current standard addresses only the "peak values" of seal strength, a revision to the test method that is under review by ASTM, includes the use of the force-deformation curve and average seal strength.

3.2.4.2 ASTM F1140

ASTM F1140 describes "Standard Test Methods for Internal Pressurization Failure Resistance of Unrestrained Packages for Medical Application".

This standard suggests beginning the test with a creep pressure that is approximately 80% of the burst value. Different seal adhesives, such as pressure-sensitive adhesives, may need a lower creep-test pressure to be effective. Inflation rate is not critical as long as the initial fill is not too fast to shock the seal or too slow to lengthen the test.

Inflation seal-strength testing of unrestrained packages (ASTM F1140) quickly and effectively evaluates a package's seal strength. However, there are no specific standards for that strength, since seal-strength values are relative to package size, geometry, materials, and bonding agents. Tests show consistent process data on packages tested under consistent, repeatable conditions. In addition, package geometry affects the interpretation of test results. For example, pouches with a long side seal will generally fail on the long seal, unless a heater failure has occurred on the shorter seal or chevron. Unsupported tray lid seals may fail at points relative to their geometry. Very flexible materials may deform with pressurization to an extent that makes seal testing difficult. To address such problems, it may be wise to use restraining plates.

Package geometry affects internal pressure distribution on package surfaces and seals. For example, a pouch unrestrained in any axis exhibits circumferential hoop stress when internal pressure is applied.

3.2.4.3 ASTM F2054

Restrained package testing, ASTM F2054, is a refinement of ASTM F1140 that has several advantages. Restrained package test data is more consistent than unconstrained package test data. A more-consistent loading on the package seal is achieved. A higher correlation exists between tensile seal-strength data and restrained package test data.

When the package is restrained, the load application is distributed directly on the seal area, and because material stretching and deformation is minimized, the test forces are more uniformly applied. In addition, package restraint has a direct relationship to burst pressure: The wider the gap between restraining plates, the lower the average burst pressure. The use of package restraints must be approached with caution. Because of pressures exerted on the plates, extreme care must be taken to ensure that fixtures are designed to withstand the forces applied by the inflated package.

The restrained creep test is being used by the military (Internal Pressure Test) for combat rations and is a good overall test for seal strength because it stresses the package uniformly in all directions and identifies the location of the weakest point.

3.2.4.4 MIL-PRF-44073-F

The following text describes in greater detail how to conduct a creep test on MRE pouches:

Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates spaced 1/2 inch \pm 1/16 inch apart. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously. Pressure shall be applied at the approximate uniform rate of 1 psig per second until 20 psig pressure is reached. The 20 psig pressure shall be held constant for 30 seconds and then released. The pouches shall then be examined for separation or yield of the heat seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure.

3.2.4.5 MIL-PRF-32004-B

The following text describes in more detail how to conduct a creep test on Polymeric Trays:

Internal pressure resistance shall be determined by pressurizing the container without protective sleeve while restrained between two rigid plates. There shall be a minimum clearance of 1/8 inch between the bottom surface of the top plate and the top surface of the tray flange (with attached lid). A four-seal tester (designed to pressurize filled container by use of a hypodermic needle through the container wall or lid) shall be used and all four seals tested simultaneously. It may also be necessary to restrain the tray body during the test within either a wood or metal base, such that excessive deflection of the tray does not render a false lid failure. Pressure shall be applied gradually until 20 psig pressure is reached. The 20 psig pressure shall be held constant for 30 seconds and then released. The container then shall be examined for separation or yield of the heat seals. Any rupture of the container or evidence of any seal separation greater than 1/16 inch or seal separation that reduces the closure seal width to less than 1/16 inch shall be considered a test failure.

3.3 Conclusions Literature Survey

It is evident that most of the test methods are intended to detect leaks in the food package. Only a few methods are aimed at the primary objective of this short term project to validate minimum seal strength. The compression test referred to in section 3.2.3 is similar to the test method considered in this project and would offer a valid alternative to the costly destructive internal pressure test.

4 Industry Survey

In the following section, the results of an industry survey will be reviewed. The main source for this section were the PackExpo website, a web search for package integrity and seal strength. Other information was collected at trade shows and plant visits.

4.1 ALPS- WI, USA

ALPS Leak INSPECTORS have several products designed for in-line, automatic leak detection and off-line manual leak detection, mainly for PET bottles. Their technology incorporates pressure sensors to determine defects such as excessive and minimum stretch, leak and gross leak.

<http://www.alpsleak.com>

4.2 MAP Systems

MAP Systems is a division of Clear Lam Packaging Inc (<http://www.clearlam.com>) and makes diagnostic equipment to analyze package burst levels and seal strength for both flexible and rigid containers. The largest MAP Systems' diagnostic line is the VBT-1100 High Capacity Vacuum Tank. It is designed with a self-contained electric vacuum pump to test both package seal strength and burst level. The test package is floated in a water-filled tank that is under vacuum. The stainless-steel VBT-1100 handles containers as large as 13.5", large enough for the half steam table tray.

<http://www.mapsystems.cc>

4.3 MOCON

PAC GUARD™ 400 is a non-destructive leak detection system designed for production line quality control and package development applications. The principle of the PAC GUARD™ 400 is based on vacuum pressure differential to detect carbon dioxide as it escapes from the package. This imposes a necessary stipulation that the package headspace contains carbon dioxide at some concentration level that can be detected against prevailing background levels. A desirable concentration of carbon dioxide in the package headspace is 10% by volume. The Pac Guard 400 can detect weak heat seals, gross leaks, or small pin holes in finished products, within seconds. Ideal applications include sterile medical supplies, food packaging, and pharmaceutical packaging. This portable system can be used to test blister packs, foil pouches, plastic pouches, thermoformed cups, bottles, boxes, and small packages. Testing works best with dry products, where some headspace exists.

<http://www.mocon.com/>

4.4 Package Technologies and Inspection

Package Technology and Inspection (PTI) markets two systems noteworthy, the Pti-525 and the Pti-325.

The Pti-525 is used for the Seal Integrity Testing of Trays, Cups, Blisters & Pouches made of TYVEK, Paper, Foil or Plastic. The Pti-525 is a non-contact inspection system using an Airborne Ultrasonic Imaging System to characterize, evaluate and inspect heat sealed layers in pouches and packages. The unit can be set up in an L-scan mode during which it scans a straight line of the seal or C-scan mode during which it will scan the entire width of the seal.

Leaks can be detected with the Pti-325 Leak Tester which uses Differential Vacuum Inspection Technology. A package is placed in a vacuum chamber and the decay in chamber vacuum is measured as an indication of package leak. Pti-325 can detect leaks down to 1 micron in vials & ampoules, as well as rigid packages.

<http://www.packagingtechnologies.com>

4.5 Precision Automation

Precision Automation develops on-line and off-line leak detection systems. It uses proven vacuum/force sensor technology to identify gross leaks, "slow leaks," weak seals and/or excess residual gas in a package, based on vacuum force decay.

<http://www.precisionautomationinc.com/leakdetection.html>

4.6 TapTone

TapTone's PBI-100 Inspection System (formerly known as Squeezer) finds and rejects leaking and damaged plastic containers at line speeds of up to 200 feet per minute. The system is designed with dual parallel chains, cantilevered over an existing conveyor system to apply force to the sidewall of the container. This action compresses the headspace of the container which allows a comparative measurement to be taken at both the in-feed and discharge of the system. The controller analyzes these measurements and rejects the container if the difference is excessive.

<http://www.taptone.com/>

4.7 TM Electronics

TM Electronics, Inc. is a leading manufacturer of high quality leak and flow testers, package testers, and trace gas detectors for custom engineered systems. <http://www.tmelectronics.com/>

The TM Electronics BT-1000 Automated Package Tester provides destructive, seal strength and package integrity testing capability in one instrument. It also provides the documentation necessary for package process validation, for in-process inspection or post-process audit testing. The BT-1000 performs a pressure decay leak test by charging the package volume with air, and then measuring the change in pressure due to leaks.

http://www.tmelectronics.com/prod_BT_1000.htm

The TME SOLUTION-C Test System is a Closed Chamber Test Method that provides fast, non-destructive testing of sealed flexible food packages or induction welded bottle seals. The system is comprised of the TME Solution™ leak test instrument and a chamber fixture. The chamber fixture encloses the package and is pressurized (or evacuated for a vacuum test), stabilized and tested for pressure (or vacuum) decay that would indicate leakage. Usually, a rigid container will use the pressurization method and a flexible container will use the vacuum method.

http://www.tmelectronics.com/prod_solution_C.htm

4.8 Uson

Uson has several off-line and on-line systems to be used for leak testing of food packaging. Most of their systems are based on vacuum-force decay.

<http://www.uson.com/>

4.9 Wilco System

The WILCOMAT ® US is a testing system based on ultrasound technology for fully automatic in-line seal testing on cups, trays and bags. The system detects wrinkles, incomplete seals, leaks, impurities at production speed and provides results in real time. Contact between sensor and seal is made by water since ultrasonic sound travels with a much higher frequency in this media. The higher frequency results in the considerably better fault detection sensitivity needed for most application

http://www.wilco.com/english/products/food_seal.asp

4.10 Miscellaneous Web Links

In this section, we document some of the remaining links that were found in our web search. These links will give the reader some additional information in the area of container inspection.

The following is a link to a presentation on leak and seal strength testing
<http://www.msu.edu/~tanprase/PKG%20452/PKG%20452%20Lab%2010%20Integrity.pdf>

The following is a link to a paper describing the relationship between burst and peel strength data.
<http://www.carltech.com/tap/burstpeel.pdf>

The following is a link to the Canadian Food Inspection Agency manual for flexible retort pouches
<http://www.inspection.gc.ca/english/anim/fispoi/manman/pousac/chap4e.shtml>

The following is a link to the FDA, Center for Food Safety and Applied Nutrition On-line Bacteriological Analytical Manual.
<http://vm.cfsan.fda.gov/~ebam/bam-22c.html>

5 Conclusion Industry Survey

The PTI and Wilco container integrity testers send ultra sonic energy through the seal area and measure the absorption of the energy as an indicator of seal abnormalities. The Wilco system uses water as a media between sensor head and seal. The PTI system uses air. This technology is currently being investigated by the University of Tennessee under STP#2011.

Most of the other commercial inspection systems are designed to check for container integrity based on pressure differential between the inside and outside of the container. Either, they measure pressure decay or force decay as an indicator for loss of container integrity. Flow rate through a “hole” is, however, dependent on the hole size, the pressure differential and the consistency of the product flowing through the hole. Therefore, systems designed for containers that have air in the area where the defect is expected have a higher rate of success to detect the hole than do systems that need to detect holes where viscous or solid material have to flow through the “hole”. The Mocon system is slightly different from the previously mentioned systems by its ability to detect CO₂ in the headspace. Some of these systems have been evaluated and tested in previous CORANET short term projects. STP1020: “Polymeric Tray Integrity Testing” evaluated a non-destructive vacuum test method for half steam table trays.

The non-destructive vacuum test method, evaluated in STP#1020, also generates a force over the seal area. This force is, however, a function of the residual gas that is inside the container and the degree of expansion of the tray that is allowed within the test chamber. In general, these forces are much lower than required to distinguish between a good and a marginal seal.

The system described by TapTone uses a compression force to create a pressure differential between the internal and external side of a flexible or semi rigid container. It determines if the container is leaking. The force and pressure differentials that this tester can generate are much higher than the force generated by vacuum systems. The TapTone system comes closest to the static load test referred to by Lampi in 1976 and referenced to by the FDA in their “Bacteriological Analytical Manual Online” and by the Canadian Food Inspection Agency in their “Flexible Retort Pouch Defects Identification and Classification Manual”. TapTone, however, does not have an offline system available that could conduct a compression test on polymeric trays and quantify pass/fail on seal strength.

6 Recommendation

The package seal strength measurements and analyses are usually done by destructive methods. Most of the non-destructive testing methods focused on leak detection, rather than quantification of a minimum seal strength. At present, no commercial method has been identified that is capable of quantifying or assessing the seal (e.g. tack, creep) strength non-destructively, similar to the one quoted by Lampi and referred to by the FDA and by the Canadian Food Inspection Agency.

Lampi's static compression method was aimed at the MRE pouch and did not address semi rigid containers, such as the Polymeric Tray. It warrants, therefore, further investigation to refine this method for polymeric trays. It has the potential to generate similar forces as currently specified by the destructive internal pressure test, without destroying the container. In addition to the static compression test method, the test methodology could be expanded to include sudden impact force and/or cyclic forces. A container is typically exposed to a combination of these forces during shipping.

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COMBAT RATION NETWORK FOR TECHNOLOGY IMPLEMENTATION

Non Destructive Seal Tester Test Data

Technical Working Paper (TWP) #220

Henderikus Bruins

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1. Introduction

Seal strength measurements and analysis of flexible and semi-ridged containers are usually done by destructive methods. Most of the non-destructive test methods focus on leak detection and seal integrity, rather than quantification of the seal strength. At present, there is no method capable of quantifying or assessing the seal (e.g. tack, creep) strength non-destructively. Short Term Project 2016 was assigned to develop a prototype, non-destructive (ND) test system based on static compression of the polymeric half steam table tray. It should expose the seal to forces that would open the seal if the seal strength is insufficient. If successful, the ND tester would replace the traditional internal pressure test method.

In the internal pressure test protocol, the tray is confined between two plates that are 1/16" to 1/8" taller than the tray and air is injected into the tray to generate a 20 psig internal pressure and held for 30 seconds. The internal pressure test is, however, known to pass seals of marginal quality that have sections of non-fusion seals. In developing the test conditions for the non destructive seal tester, consideration will be given to reject trays that contain non-fusion seals. Thus the quality standard for minimum required seal strength will be raised.

2. Objective

- Determine seal conditions for the Raque Heat Sealer that will produce trays with a wide range in seal quality. These trays will then be used to test and compare the results from the ND test, the peel strength test and the conventional IP test.
- Develop a Test Protocol for Non Destructive Testing of Polymeric Trays as a replacement for the IP test protocol and propose accept/reject criteria.
- Develop a Test Protocol for Non Destructive Testing of Polymeric Trays that have visual defects and establish the relationship between the visual defect and the overall performance of the container.
- Validate both Test Protocols with production samples from current and past producers.

3. Experimental Phase

3.1. Establishing Sealing Conditions, Part I

3.1.1. Sample Preparation

To determine sealing conditions for the Raque Heat Sealer in order to produce trays with a wide variety in seal quality, trays were filled and sealed using four different heat seal temperatures (350 F, 370 F, 390F , 410F), using a seal time of 3.5 sec., 80 psig seal pressure and a vacuum setting of 1.0 sec. The

recommended production conditions for this heat sealer are: 410 F for 3.5 sec. at 80 psig and 1 sec of vacuum. Lower temperatures and/or shorter seal times should make a weaker seal. To study the impact of retorting on the seal strength, half of the trays were retorted at 250 F for 100 min, a typical retort process for Polymeric Trays and the remaining trays were tested without retorting.

3.1.2. Peel Force Test

After the content was removed from the tray, we cut 1" seal samples from it, two samples from each long side and one sample from each short side. The seal samples were pulled apart using 12"/minute crosshead speed and the maximum force was recorded.

3.1.3. Results

Trays that were sealed at 350 F or 370 F had sections of tacky, non fusion seals. Samples sealed at 390 F and 410 F did show good fusion seals. Trays that were retorted showed higher seal strength data than trays that had not been retorted.

	Before Retorting					
Seal Temp [F]	Seal Peel Force [N/inch]					
350	28	17	21.5	40	22	30.5
370	152.5	148	84.5	132.5	129	82
390	180	184.5	167.5	156.5	133	144
410	157.5	147.5	172.5	184	172.5	200
	After Retorting					
Seal Temp [F]	Seal Peel Force [N/inch]					
350	119.5	76	21	27.5	29	28
370	139	141	158	152.5	171	128.5
390	183	178.5	197.5	187.5	143.5	164
410	169	191	189.1	201.5	190.5	183

Table 1: Peel Strength Data

Seal Temp [F]	Seal Strength Before Retort [N/inch]		Seal Strength After Retort [N/inch]	
	Avg	Std	Avg	Std
350	26.5	8.2	50.2	39.4
370	121.4	30.9	148.3	15.2
390	160.9	20.2	175.7	19.2
410	172.3	18.6	187.4	10.8

Table 2: Summary Data Table 1

3.1.4. Conclusion

The sample size taken for the peel test was inadequate to capture the weak spots of the seal. It is recommended to double the sample size to 12 samples per tray.

Based on the test, we concluded that a seal temperature of 390 F with lower seal times would be appropriate to produce seals, ranging from acceptable, marginal and poor. Because of the impact of the retort process, we also concluded that all trays should be retorted to have consistent results.

3.2. *Establishing Sealing Conditions, Part II*

3.2.1. *Sample Preparation*

To manufacture trays with weaker seals at a seal temperature of 390 F, the seal time was reduced. A total of eight trays per sealing condition were manufactured at 2.0 sec. and 3.0 sec. seal time. Other sealing conditions remained constant (Seal Temperature 390 F, Seal pressure 80 psig, Vacuum 1.0 sec, Trays filled with 2600 gram water). All trays were retorted. Retort conditions were 100 min. @ 250 F

3.2.2. *Peel Force Test*

After the content was removed from the tray, the straight sections of flange were divided into 1" sections (8 sections on the long side and 6 sections on the short side). Seal samples were then cut (1" sections) from the tray, three samples from each side and peeled apart using 12"/minute crosshead speed. The maximum force for each sample was recorded for each sample number (the numbering started on left top side, clockwise around with tray recycle symbol towards operator).

3.2.3. *Results*

Four Trays of each condition were tested. The maximum peel strength data can be seen in Table 3. Data from the 2.0 sec. population that had non fusion seals is marked **bold**

After Retort Seal Strength Data												
	1	5	8	9	12	14	15	19	22	23	26	28
Seal Temp [F]	Seal Peel Force [N/inch]											
390 F for 2 sec	129	116	122	130	146	146	141	141	143	127	140	136
	140	116	72	143	132	141	108	130	149	135	137	136
	130	140	127	140	127	131	125	138	81	146	139	139
	127	130	130	137	127	133	91	80	149	133	149	137
Seal Temp [F]	Seal Peel Force [N/inch]											
390 F for 3 sec	171	191	191	136	152	145	182	164	172	144	128	163
	197	153	195	160	168	150	151	167	164	142	135	142
	160	174	140	148	145	170	179	197	174	152	140	159
	170	128	136	142	140	144	149	156	192	149	148	154

Table 3: Peel Strength Data

Temp [F]	Time [sec]	Avg [N/inch]	Std [N/inch]	Min [N/inch]
390	2.0	130.0	17.4	72.0
390	3.0	158.5	18.8	128

Table 4: Summary Data Table 3

Trays from the same population were also tested via the Internal Pressure protocol. All trays from the 3.0 sec. population passed the IP test. All trays, except one, from the 2.0 sec. population passed the IP test. The one tray that failed the IP protocol had a narrow seal (<1/16") after the test.

3.2.4. Conclusion

Based on the results of the test, we concluded that seal times of 2.0 sec. and 3.0 sec. at 390 F seal temperature would generate two populations of tray samples that would have marginal poor seals with locations of non fusion seals (2.0 sec.) and marginal acceptable seals with full fusion seals (3.0 sec.). These two populations would form the basis for the static compression conditions that would have to yield a high fail rate in the 2.0 sec sample and a high pass rate in the 3.0 sec sample.

3.3. Film Structure

The Demo facility had access to two different film structures. The initial tests were done on film from Smurfit and Stone. The final test work was done using a film that was supplied by MI Resources from Japan. Before changing film types, we needed to establish the difference in performance between these two film sources.

3.3.1. Characterization:

To characterize the strength of the film, we tested both films first by stretching 1" film samples

Test conditions:

- Starting distance: 6"
- Test speed: 5 mm/sec
- Strip width: 1"
- Strip length: 6" (i.e. the starting distance)
- Both films were analyzed for yield point, breakpoint and strain at break in both directions (Length and Cross) of the roll stock.

		Yield Force	Break Force	Yield @ Break
Smurfit	Length	120 N/inch	170 N/inch	39%
	Cross	100 N/inch	180 N/inch	39%
MI Resource	Length	100 N/inch	180 N/inch	65%
	Cross	80 N/inch	180 N/inch	59%

Table 5

It can be seen that the Smurfit has a slightly higher yield force than the MI Resource film. The yield force is the maximum force that the film can be exposed to before it is permanently deformed. Both films failed at about the same force, but the MI Resource film elongated much more than the Smurfit film before it failed.

3.3.2. Sample Preparation

To characterize the sealing performance of each film 24 trays per sealing condition (2.0 and 3.0 sec seal time and two films) were manufactured. Other sealing conditions remained constant (Seal Temperature 390 F, Seal pressure 80 psig, Vacuum 1.0 sec, Trays filled with 2600 gram water). All trays were retorted. Retort conditions were 100 min. @ 250 F.

3.3.3. Testing

3.3.3.1. Internal Pressure Test

A total of 32 trays, 8 of each condition, were exposed to an internal pressure test. All but one tray passed the test. The one tray that was rejected was rejected due to a post test seal width < 1/16".

Film Type	Seal Condition	Samples	IP Test
Smurfit	390 F / 2 sec	8	8 passed
	390 F / 3 sec	8	8 passed
MI Resource	390 F / 2 sec	8	7 passed/ 1 failed
	390 F / 3 sec	8	8 passed

Table 6

3.3.3.2. Peel Force Test

Sixteen trays, four of each condition, one from each sealing head were tested for peel strength. As can be seen, the average bond strength for the Smurfit film is higher under identical seal conditions.

		1	5	8	9	12	14	15	19	22	23	26	28
Seal Temp [F] 390 F/2.0 sec Smurfit Film		Seal Peel Force [N/inch]											
	1	111	104	122	124	124	124	78	82	68	130	115	120
	2	144	109	104	132	142	114	126	84	77	101	131	125
	3	116	98.5	131	121	132.5	128	119	141.5	114.5	160.5	132.5	127
	4	168	166	160	132	135	120	110	110	120	152	118	131
Seal Temp [F] 390 F/3.0 sec Smurfit Film		Seal Peel Force [N/inch]											
	1	173	145	154	169	166	151	122	138	178	154	164	158
	2	180	169	118	166	137	124	162	122	105	131	164	142
	3	164	144	124	142	125	124	149	124	184	172	124.5	120
	4	172	160	165	180	177	181	180	168	143	159	172	183

Seal Temp [F]		Seal Peel Force [N/inch]											
390 F/2.0 sec	1	88	86	113	95	108	125	91	93.5	84	107	110	109.5
Jap Film	2	91.5	92.5	98.5	111	100	100	96	70.5	87.5	102	94.5	110.5
	3	79	128	97.5	95	105	101	83.5	75	82.5	112	112	121.5
	4	91	116	92	95	114.5	98	104	87	87	112	103	121.5
Seal Temp [F]		Seal Peel Force [N/inch]											
390 F/3.0 sec	1	114	130	102	131	120	111	114	169	160	106	114	105
Jap Film	2	166	166	124	112	130	118	91	156	167	116	114	99
	3	109	162	88	112	136	117	131	139	169	121	125	129
	4	179	175	132	177	184	136	104	156	116	136	114	125

Table 7

Film Type	Seal Condition	Average [N/inch]	Std Dev [N/inch]	Min [N/inch]
Smurfit	390 F / 2 sec	121.6	21.9	68
	390 F / 3 sec	152.7	21.8	105
MI Resource	390 F / 2 sec	99.5	13.1	70.5
	390 F / 3 sec	131.4	25.5	88

Table 8

3.3.3.3. Static Compression Test

After several trials, we used the following static compression condition and post test evaluation criteria:

- 60 psig on the compression stroke of the lower piston: P_1
- 10 psig on the decompression stroke of the lower piston: P_2 . By having the decompression pressure set at all times, the decompression time would be faster. This could possibly minimize product spillage in case of catastrophic seal failure.
- The resulting compression force equals 1,429 psig
$$F = P_1 \pi D^2 / 4 - P_2 (\pi D^2 - \pi d^2) / 4$$

D: diameter of the piston = 6.000 "
D: diameter of piston rod = 1.375"
- The minimum seal width will be evaluated after the test and if the remaining seal width is less than 1/16", the test would be a failure.

Results

Film Type	Seal Condition	Samples	Pass	Fail
Smurfit	390 F / 2 sec	8	1	7
	390 F / 3 sec	8	8	0
MI Resource	390 F / 2 sec	8	0	8
	390 F / 3 sec	8	7	1

Table 9

As can be seen, the conditions of the static compression test for 60-10 psig for 60 seconds resulted in a high failure rate in the 2 sec. population and a high pass

rate in the 3 sec. population. The seals with the Japanese film are slightly weaker than the seals made with the Smurfit film. This is consistent with the peel strength data.

3.4. Static Compression Test: Destructive/Non-Destructive

The next question that needed to be answered was whether the static compression test would weaken the strength of the seal. Two tests were performed. The first test was a sequential compression test on eight different trays from the 3 sec. population. Each tray was compressed three times, using the standard conditions (60-10 psig for 60 sec.). None of the trays failed during the subsequent compression test. Next, we increased the number of sequential compression tests to five. One tray sealed with the Smurfit film failed on the fifth compression cycle due to delamination.

As a second test, we compared average peel strength data from before and after a compression test.

3.4.1. Results

Film Type	Seal Condition	ND Test	Peel Test Data [N/inch]		
			Average	Std Dev	Min
Smurfit	390 F / 3 sec	Before	152.7	21.8	105
		After	142.4	23.1	68
MI Resource	390 F / 3 sec	Before	131.4	25.5	88
		After	126.5	24.9	87

Table 10, peel strength summary data

Statistical analysis of the peel strength data shows a slight but statistically significant decrease in peel strength due to the preceding compression test for the Smurfit film (~10 N/inch). No statistically significant degradation could be demonstrated in the Japanese film.

3.4.2. Conclusion:

The compression test did not weaken the seals made from either film so that the tray would fail in a subsequent compression test. Trays from the 3 sec. population withstood at least three additional compression cycles. In the peel test data, we observed some weakening in the older film from Smurfit, a film that had shown a greater tendency to delaminate than the newer film from MI Resources.

Film behaves differently due to age, adhesive bond strength and tensile strength data. Therefore we recommended that every producer executes a sequential compression test and a peel test on samples before and after the compression

test to assure that the test is truly non destructive for the film materials that are being used. The lid material of a well sealed tray should withstand, at least, three consecutive compression tests without failure.

3.5. *Drop Test*

The next question that needed to be answered was: “Will the trays that pass the ND test, pass a standard drop test (ASTM D5276, Assurance Level I for a series of 10 drops) while packed in Military Specified Packaging Material. (Mil-PRF-32004B)

We used trays that were filled with water and sealed at 390 F at 1.5, 1.75, 2.0 and 3.0 sec. and retorted for 100 min. @ 250 F. Trays were packed in sleeves, four to a box, according to Military Specifications. The case was then dropped according to the ASTM protocol. None of the 2.0 sec. and 3.0 sec. trays failed. Trays that were sealed with 1.5 sec. and 1.75 sec. did exhibit failure during the drop test. Trays that passed the drop test were then tested in the compression test. Trays from the 2.0 sec. population failed the compression test, indicating the compression test is more severe than the drop test and that trays that pass the compression test will pass the drop test. Because the 2.0 sec. trays had sections of non fusion seals, it can also be that trays that have a strong tacky, but non fusion seal could survive a drop test.

One could argue, therefore, that the ND test protocol is too severe and not required to assure survivability of the tray in the distribution system. The current ND test conditions were designed to reject tacky, non fusion seals. If overwhelming evidence can be made available that strong, tacky seals are acceptable, the compression force of the tester can be lowered by using a lower pressure on the compression stroke.

3.6. *Product Trays*

So far all of the testing had been done on trays filled with water. The question that needed to be answered was if the tester would be applicable for all foods or if there would be any restrictions to the type of food that can be inside the can. Of particular concern, were products that contained little or no liquids (rice) and products that had placeables. We received from a producer a variety of products:

- Mashed Potatoes with Flavored Chicken Gravy,
- Sweet and Sour Pork,
- Meat Balls in Gravy,
- Imitation Pork Riblets in BBQ Sauce,
- Cherry Dessert,
- White Rice,

Two trays of each product were tested following the standard conditions (60-10 psig for 60 sec.)

3.6.1. Results

		Fill Weight	Min Seal Width	Comments
Mashed Potatoes	8940-01-44-5737	96.7 oz	0.145	Pass
Mashed Potatoes	8940-01-44-5737	96.6	0.190	Pass
Sweet & Sour Pork	8940-01-504-4246	99.8 oz	0.185	Pass
Sweet & Sour Pork	8940-01-504-4246	98.3	0.130	Pass
Meat Balls	8940-01-455-1873	98.3 oz	0.250	Pass
Meat Balls	8940-01-455-1873	96.0	0.045	Narrow Seal
Pork Riblets	8940-01-455-1882	87.0 oz	0.175	Pass
Pork Riblets	8940-01-455-1882	89.7	0.205	Pass
Cherry Dessert	8940-01-455-1870	101.0 oz	0.125	Pass
Cherry Dessert	8940-01-455-1870	101.3	0.175	Pass
White Rice	8920-01-445-5736	95.9 oz	0.185	Pass
White Rice	8920-01-445-5736	95.9	0.105	Pass

Table 11

All product trays behaved acceptably in that the seals were strained right away. This indicates that hydraulic movement of the product and air inside the tray in response to the compression force occurs. After inspection of the content, no product damage was observed.

One tray exhibited seal creep less than 1/16" and according to the proposed protocol, this tray would fail the test. The creep which occurred in the middle of the long side of the tray was a typical indication that seal contamination had taken place. There were, however, no external indications prior to the test that the seal was or had been contaminated in this area. This observation is important to note because the ND test method might require improved clean up procedures for seal contamination.

Note: It should be noted that bakery products packed in polymeric trays are not suitable for testing in the ND tester. Inadequate hydraulic movement and compressibility of the product prevents pressurization of the tray seals and product characteristics are affected by the compression. A more appropriate test for this product might be an under-water vacuum test

3.7. Validation Testing

3.7.1. Seal Anomalies

Next, we studied the impact of seal anomalies on overall seal strength. A total of 62 product trays, spread over 6 products, were obtained from a producer that had set aside these trays due to potential seal problems. The trays were sorted into two categories, one with visual defects (32) and one without visual defects (30). Each tray was tested in the static compression test using the standard conditions (60-10 psig for 60 sec.). The proposed interpretation of the data would be: If the remaining minimum seal width is more than 1/8", the visual defect had no impact on the performance of the tray and the defect would not be scorable. If the remaining minimum seal width is between 1/16" and 1/8", the defect would be scored as a minor defect. If the remaining minimum seal width is <1/16", the defect would be scored as a critical defect.

3.7.1.1. Results

Of the 32 trays with visual defects, 28 trays passed the test with seal width of more than 1/8" and thus, the defect was not scorable. Three trays demonstrated minor seal creep with a remaining minimum seal width >1/16, <1/8", hence the defect was minor. One tray crept to a seal width < 1/16" which made the defect critical.

Code	Product	Visual Defect	ND Result	Comment
10C	Chili with Beans	Y	Critical Defect	Seal width = 0.045"
10A	Chili with Beans	Y	Minor Defect	Seal creep= 0.075"
11B	Apple Dessert	Y	P	
14A	Buffalo Chicken	Y	P	
14B	Buffalo Chicken	Y	P	
14C	Buffalo Chicken	Y	P	
14D	Buffalo Chicken	Y	P	
15A	Buffalo Chicken	Y	P	
15B	Buffalo Chicken	Y	P	
15C	Buffalo Chicken	Y	P	
15D	Buffalo Chicken	Y	P	
16A	Buffalo Chicken	Y	P	
16B	Sweet & Sour Pork	Y	P	
1A	Sweet & Sour Pork	Y	P	
1B	Sweet & Sour Pork	Y	P	
1C	Sweet & Sour Pork	Y	P	
2A	Sweet & Sour Pork	Y	P	
2B	Sweet & Sour Pork	Y	P	
2C	Sweet & Sour Pork	Y	P	
2D	Sweet & Sour Pork	Y	P	
3C	Sweet & Sour Pork	Y	P	
3D	Sweet & Sour Pork	Y	P	
4A	Sweet & Sour Pork	Y	P	
4B	Sweet & Sour Pork	Y	P	

4C	Sweet & Sour Pork	Y	P	
4D	Sweet & Sour Pork	Y	P	
5D	Chicken Breast	Y	Minor Defect	Seal Width = 0.10"
6A	Chicken Breast	Y	P	
6B	Chicken Breast	Y	P	
8C	Chicken Breast	Y	P	
8D	Chicken Breast	Y	P	
9C	Chili with Beans	Y	Minor Defect	Seal Width = 0.090"

Table 12

It should be noted that the seal creep in the trays did not occur in the area where the visual defect was observed, but in an area near the visual defect.

Of the 30 trays that had no visual defects, 28 trays passed the test with seal width of more than 1/8". Two trays failed the test due to seal burst.

Code	Product	Defect	ND P/F	Reason Fail
10D	Chili with Beans	N	F	Burst
9A	Chili with Beans	N	F	Burst
10B	Chili with Beans	N	P	
11A	Apple Dessert	N	P	
11C	Apple Dessert	N	P	
11D	Apple Dessert	N	P	
12A	Apple Dessert	N	P	
12B	Apple Dessert	N	P	
12C	Apple Dessert	N	P	
12D	Apple Dessert	N	P	
13A	Apple Dessert	N	P	
13B	Apple Dessert	N	P	
13C	Apple Dessert	N	P	
13D	Apple Dessert	N	P	
1D	Sweet & Sour Pork	N	P	
3A	Red Beans	N	P	
3B	Red Beans	N	P	
5A	Chicken Breast	N	P	
5B	Chicken Breast	N	P	
5C	Chicken Breast	N	P	
6C	Chicken Breast	N	P	
6D	Chicken Breast	N	P	
7A	Chicken Breast	N	P	
7B	Chicken Breast	N	P	
7C	Chicken Breast	N	P	
7D	Chicken Breast	N	P	
8A	Chicken Breast	N	P	
8B	Chicken Breast	N	P	
9B	Chili with Beans	N	P	
9D	Chili with Beans	N	P	

Table 13

Summary:

- 32 trays had visual defects. Impressions and/or seal wrinkles
 - 28 trays had non scorable defects, seal width $> 1/8$ " (87.5%)
 - 3 minor: seal width $> 1/16$, $< 1/8$ " (9.4%)
 - 1 critical: seal width $< 1/16$ " (3.1%)

Note: seal creep did not occur in areas where visual defect was observed (Tray 9C, Tray 10A and Tray 10C)

- 30 trays had no visual defects
 - 28 passed
 - 2 failed (seal burst)

3.7.1.2. Conclusion:

While visual defects in the seal might be an indication that seal contamination has occurred, the results did not indicate that the particular area in which the defect was observed is any weaker than the adjacent areas. Also we could not conclude that weak and/or contaminated seals always result in visual indicators. Therefore, the effectiveness of the visual inspection system can be questioned, as it is difficult to sort out weak seals based on visual indicators.

It is of utmost importance that seal contamination is avoided during the filling process. If contamination occurs, proper cleaning procedures must be in place to remove the effects of the contamination. Alternately sealing conditions might need to be developed that would result in strong fusion seals in spite of seal contaminations. The ND tester should be used by the producer to study the effects of seal contamination and validate that cleaning procedures are effective.

3.7.2. ND Test versus IP Test

3.7.2.1. Results and Conclusion:

In order to validate the tester as a replacement of the IP tester, trays from five different lots, spread over four products were received. The product was manufactured by three different producers. The results of this validation test are summarized in a separate technical working paper (#221).

The results of this validation test were:

- All five lots passed the IP test
- Only four of the five lots passed the ND test
- Samples of the failed lot were sent to Natick who confirmed that the seal strength of this lot was substandard

The conclusions of this validation test were:

- Seals that passed the IP test may fail the ND test. Thus a higher seal quality standard is required to pass the ND test
- Regardless of the test used (IP or ND), the remaining minimum seal width of a tray with good quality seals is statistically similar.

**COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION**

Validation Test Report

**Non Destructive Seal Tester versus Internal Pressure Test
for End Item Inspection**

Technical Working Paper (TWP) #221

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1. Objective:

Validate the Non Destructive Tester as a method for detecting weak/non fusion seals compared to the currently used Internal Pressure Tester.

2. Back Ground:

Short Term Project 2016 developed a Non Destructive (ND) Tester for polymeric trays using compression force to generate an internal pressure in the tray. The internal pressure is approximately the same pressure used in the current IP test method, but due to the geometry of the top compression plate, much higher peel forces on the seal can be created. As a result, the tester is able to detect non fusion seals more reliably.

There are two issues of concern with the current Internal Pressure test:

- the IP test is destructive which adds significantly to the cost of this quality assurance test.
- the IP test is not reliable in detecting weak seals because inadequate forces are generated on the seal to detect partial non fusion seals.

Test conditions were developed for the ND tester that rejected a majority of trays with non fusion seal sections and passed trays with full fusion seals. In the final phase testing, conditions needed to be validated on trays with a range of products and produced under high speed production conditions.

3. Validation Test Method:

To validate the ND tester as a replacement for the destructive IP tester, a two step validation protocol was used. Half the trays were exposed to the IP-ND test and the other half to the ND-IP test, using the IP and ND test protocols.

IP-ND Test: Select 5 trays from each lot. First, test each tray using the destructive internal pressure tester. If the tray passes this test, seal the punctured hole in the lid-stock with duct tape and test the tray using the ND tester. Pass/Fail results in both tests shall be recorded. Failed trays should be further inspected to determine the reason of failure (delamination, lid-stock failure, seal creep, open seal, etc.) and after peeling away the lid stock, the minimum width of the fusion seal shall be recorded.

ND-IP Test: Select 5 new trays from each lot . First, test each tray using the ND tester. If the tray passes this test, test the tray using the IP test. Pass/Fail results of both tests shall be recorded and again, the seal of a failed tray shall be inspected to determine why the tray failed and to determine the minimum width of the fusion seal.

Test results of the combined sample set shall be tabulated and statistically analyzed to confirm the hypothesis that the ND tester is equal or better in detecting weak seals. Once it is confirmed that the ND tester is as effective in detecting non fusion seals, the ND tester can be used as a replacement for the IP test.

3.1. Internal Pressure Test Protocol.

Internal pressure resistance shall be determined by pressurizing the container without protective sleeve while restrained between two rigid plates. There shall be a minimum clearance of 1/8 inch between the bottom surface of the top plate and the top surface of the tray flange (with attached lid). A four-seal tester (designed to pressurize filled container by use of a hypodermic needle through the container wall or lid) shall be used and all four seals tested simultaneously. It may also be necessary to restrain the tray body during the test within either a wood or metal base, such that excessive deflection of the tray does not render a false lid failure. Pressure shall be applied gradually until 20 psig pressure is reached. The 20 psig pressure shall be held constant for 30 seconds and then released. The container then shall be examined for separation or yield of the heat seals. Any rupture of the container or evidence of any seal separation greater than 1/16 inch or seal separation that reduces the closure seal width to less than 1/16 inch shall be considered a test failure.

3.2. Non Destructive Test Protocol.

The following protocol was used for the ND Test:

- Inspect the seal width prior to the test. If the seal width is less than 1/8" select another tray.
- If the minimum seal width is equal or more than 1/8", test the tray in the non-destructive seal strength tester. Compress the tray between two plates, the top plate outer perimeter is 1" within the flange of the tray, allowing the lid stock to bulge up and strain the seal. The bottom plate is shaped according to the oval indentation of the bottom of the tray. Apply a compression force of 1400 lbf. on the tray and hold for 60 seconds.
- After the test, remove the tray from the tester and re-inspect the seal. If the minimum seal width yielded to less than 1/16", reject the tray. If the minimum seal width is 1/16" or more, pass the tray.

3.3. Recorded Data

The following Test Data was collected:

- Date:
- Product Name
- Lot Number
- Pass/Fail IP Test
- Reason Fail IP Test
- Pass/Fail ND Test

- Reason Fail ND Test
- Appearance of any Seal Anomalies before and after testing

3.4. Materials

Finished product trays were obtained from government inventory (Tracey). The sample set included five lots, four products and three producers, as can be seen in the table below.

Product Code	Description	Producer Code	Lot #	Qty Used [Case]
CBH	Corn Beef Hash	AA	3207	6
CBH	Corn Beef Hash	AA	3200	3
PWB	Potato with Bacon	BB	3170	18
CCM	Chicken Chow Mein	CC	3276	9
BPB	Beef Patties	BB	3063	6

Each lot was split into sub-lots based upon cook numbers, whenever possible. This resulted in 14 Test Codes, each test code consisting of 12 trays:

Test Code	Product Code	Lot #	Cook #
A	CBH	3207	8-3 & 10-1
B	CBH	3207	11-1 & 11-3
C	CBH	3200	11-1 & 7-1
D	PWB	3170	4FJ
E	PWB	3170	15AH
F	PWB	3170	25AJ
G	PWB	3170	25AJ
H	PWB	3170	25AJ
I	PWB	3170	25AJ
J	CCM	3276	212&227
K	CCM	3276	213 & 314
L	CCM	3276	315 & 416
M	BPB	3063	25FH
N	BPB	3063	11FK & 25FH

Each Test Code was then used for the validation test.

3.5. Results:

A total of 70 trays were tested first by the internal pressure test, followed by the ND test (IP-ND). A total of 65 trays were first tested in the ND tester, followed by the IP test. Ten trays failed the ND test and were not tested in the IP test. A total of 260 test

observations were recorded. The results of the tests were tabulated in an Excel spreadsheet (see appendix) and analyzed with StatGraphics software, version 5.0.

The breakdown of test observations per test was:

	IP	ND	Total
IP-ND	70	70	140
ND-IP	55	65	120
Total	125	135	260

The breakdown of the test observations per product was:

Product	IP-ND	ND-IP	Total
BPB	20	20	40
CBH	30	30	60
CCM	30	10	40
PWB	60	60	120
Total	140	120	260

The breakdown of the test observations per producer was:

Producer	IP-ND	ND-IP	Total
AA	30	30	60
CC	30	10	40
BB	80	80	160

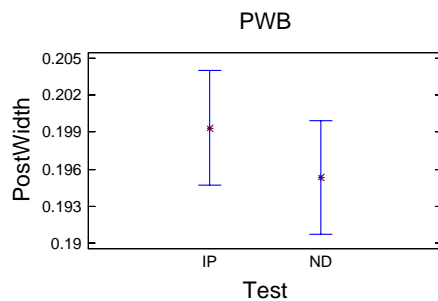
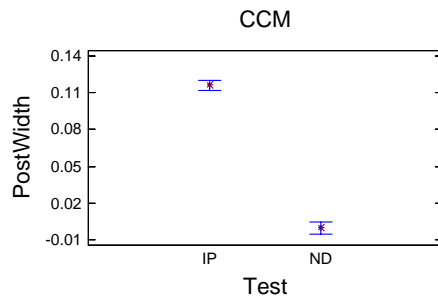
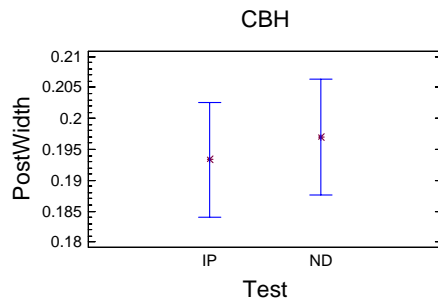
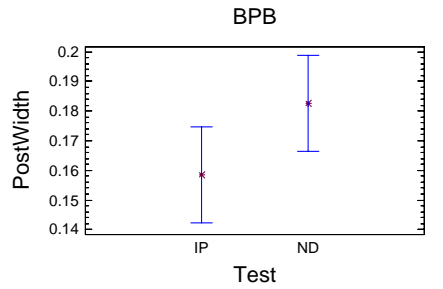
The mean minimum seal width after the IP test (as the first test) was:

Level	Count	Mean [inch]
Grand Mean	70	0.167
Product		
BPB	10	0.159
CBH	15	0.193
CCM	15	0.116
PWB	30	0.199

The mean minimum seal width after the ND test (as the first test) was:

Level	Count	Mean [inch]
Grand Mean	65	0.144
Product		
BPB	10	0.183
CBH	15	0.197
CCM	10	0.0
PWB	30	0.195

Analysis of the mean minimum seal width for products BPB, CBH and PWB was much wider than 1/8" with no significant statistical difference. There was, however, significant difference between the mean minimal seal width for the CCM product, depending on the test that was performed. The seals were narrower than 1/8" after the IP test, but the creep was less than 1/16". Thus, all product trays passed the IP test. However, all of the CCM product trays failed the ND test (burst)



Next, we analyzed the minimum seal width after each test of the IP-ND protocol and after each test of the ND-IP protocol to determine if, during the second test significant additional seal creep occurred.

Mean minimum seal width per product lot after each test during the IP-ND protocol:

Lot #	Product	IP=1	ND=2
3063	BPB	0.159	0.155
3170	PWB	0.199	0.192
3200	CBH	0.202	0.202
3207	CBH	0.189	0.182
3276	CCM	0.116	0.0

No statistical significant differences in minimum seal width exist between the first test (IP=1) and the second test (ND=2) with the exception of lot 3276 (CCM) which had substandard seal strength.

Mean minimum seal width per product lot after each test during the ND-IP protocol:

Lot #	Product	ND=1	IP=2
3063	BPB	0.183	0.182
3170	PWB	0.195	0.194
3200	CBH	0.225	0.225
3207	CBH	0.183	0.181
3276	CCM	0.0	X

No statistical significant differences in minimum seal width exist between the first test (ND=1) and the second test (IP=2) with the exception of lot 3276 (CCM) which could not be tested by the IP test, as the seals had failed during the ND test.

Mean seal creep per product lot during the second test of each test protocol:

Lot #	Product	IP=2	ND=2
3063	BPB	0.0005	0.0040
3170	PWB	0.0013	0.0072
3200	CBH	0	0
3207	CBH	0.002	0.007

Statistical significant differences exist for seal creep during the second test (IP=2 and ND=2). The mean seal creep during the second ND test (lot 3276 excluded) was 0.005". The mean seal creep during the second IP test (lot 3276 excluded) was 0.001".

3.6. Conclusions:

- **The ND test fails seals that pass the IP test. Thus a higher seal quality standard is required to pass the ND test**
- **Seal width of trays with good quality seals is statistically similar after the IP and after the ND test. Seal width of trays with marginal quality seals is significantly less after the ND test than after the IP test.**
- **The ND test will cause between 0.0 to 0.01" additional seal creep on good quality seals after the initial IP test condition. The seal creep is less than the variation in seal width typically seen in a population of well sealed trays.**

3.7. Discussion:

3.7.1. Lot 3276

Lot (3276/CCM) was pulled from Government Inventory, which means that the trays from lot 3276 passed both the Company's IP test, as well as the USDA IP test. The lot also passed Rutgers' IP tests. The lot had narrow, but acceptable, initial minimal seal width ($\geq 0.125''$) and passed the IP test. The remaining seal width was more than $0.0625''$ and the creep was less than $0.0625''$. Samples of this lot were also sent to Natick for confirmation testing using Natick's IP tester. None of the four trays burst, i.e., blew open. The trays did, however, fail Natick's IP test method, because of too much seal creep during the test. Seal creep ranged from $1/16''$ to $1/8''$.

It should be noted that because of the difference between Natick's IP test and the vendors IP test results, a more detailed definition of the IP test protocol or tester might be required.

All trays from lot 3276 failed the ND test. Upon inspection of the seal, it was observed that the seal had failed in the polypropylene layer, without leaving lid material behind on the tray flange. This indicates a tacky or non-fusion seal. A fusion seal is typically stronger than the laminate structure and lid material will remain on the tray flange after pulling it apart. Therefore, we conclude that the ND test protocol is able to detect weak/non-fusion seals that pass the IP test.

3.7.2. Seal Creep

The IP test protocol for pass/fail criteria states that: "Any rupture of the container or evidence of any seal separation greater than $1/16$ inch or seal separation that reduces the closure seal width to less than $1/16$ inch shall be considered a test failure".

We recommend that the requirement for maximum seal separation, greater than $1/16''$ is eliminated from the accept/reject criteria for the ND test method. We believe that, if the

remaining seal width after the compression test is more than 1/16", the performance of the tray is adequate.

4. Appendix: Test Results

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
A	IP-ND	ND	CBH	3207	1	0	2	0.185	0.185	0	P
A	IP-ND	IP	CBH	3207	1	1	0	0.2	0.185	0.015	P
A	IP-ND	ND	CBH	3207	2	0	2	0.175	0.175	0	P
A	IP-ND	IP	CBH	3207	2	1	0	0.2	0.175	0.025	P
A	IP-ND	ND	CBH	3207	3	0	2	0.185	0.15	0.035	P
A	IP-ND	IP	CBH	3207	3	1	0	0.205	0.185	0.02	P
A	IP-ND	ND	CBH	3207	4	0	2	0.185	0.16	0.025	P
A	IP-ND	IP	CBH	3207	4	1	0	0.185	0.185	0	P
A	IP-ND	ND	CBH	3207	5	0	2	0.195	0.185	0.01	P
A	IP-ND	IP	CBH	3207	5	1	0	0.215	0.195	0.02	P
A	ND-IP	ND	CBH	3207	6	0	1	0.205	0.2	0.005	P
A	ND-IP	IP	CBH	3207	6	2	0	0.2	0.2	0	P
A	ND-IP	ND	CBH	3207	7	0	1	0.205	0.205	0	P
A	ND-IP	IP	CBH	3207	7	2	0	0.205	0.2	0.005	P
A	ND-IP	ND	CBH	3207	8	0	1	0.155	0.155	0	P
A	ND-IP	IP	CBH	3207	8	2	0	0.155	0.155	0	P
A	ND-IP	ND	CBH	3207	9	0	1	0.175	0.175	0	P
A	ND-IP	IP	CBH	3207	9	2	0	0.175	0.175	0	P
A	ND-IP	ND	CBH	3207	10	0	1	0.2	0.2	0	P
A	ND-IP	IP	CBH	3207	10	2	0	0.2	0.2	0	P
B	IP-ND	ND	CBH	3207	1	0	2	0.165	0.165	0	P
B	IP-ND	IP	CBH	3207	1	1	0	0.175	0.165	0.01	P
B	IP-ND	ND	CBH	3207	2	0	2	0.225	0.225	0	P
B	IP-ND	IP	CBH	3207	2	1	0	0.175	0.225	-0.05	P
B	IP-ND	ND	CBH	3207	3	0	2	0.185	0.185	0	P
B	IP-ND	IP	CBH	3207	3	1	0	0.2	0.185	0.015	P
B	IP-ND	ND	CBH	3207	4	0	2	0.195	0.195	0	P
B	IP-ND	IP	CBH	3207	4	1	0	0.195	0.195	0	P
B	IP-ND	ND	CBH	3207	5	0	2	0.195	0.195	0	P
B	IP-ND	IP	CBH	3207	5	1	0	0.2	0.195	0.005	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
B	ND-IP	ND	CBH	3207	6	0	1	0.2	0.18	0.02	P
B	ND-IP	IP	CBH	3207	6	2	0	0.18	0.18	0	P
B	ND-IP	ND	CBH	3207	7	0	1	0.2	0.18	0.02	P
B	ND-IP	IP	CBH	3207	7	2	0	0.18	0.18	0	P
B	ND-IP	ND	CBH	3207	8	0	1	0.2	0.2	0	P
B	ND-IP	IP	CBH	3207	8	2	0	0.2	0.185	0.015	P
B	ND-IP	ND	CBH	3207	9	0	1	0.175	0.185	-0.01	P
B	ND-IP	IP	CBH	3207	9	2	0	0.185	0.185	0	P
B	ND-IP	ND	CBH	3207	10	0	1	0.2	0.15	0.05	P
B	ND-IP	IP	CBH	3207	10	2	0	0.15	0.15	0	P
C	IP-ND	ND	CBH	3200	1	0	2	0.225	0.225	0	P
C	IP-ND	IP	CBH	3200	1	1	0	0.245	0.225	0.02	P
C	IP-ND	ND	CBH	3200	2	0	2	0.175	0.175	0	P
C	IP-ND	IP	CBH	3200	2	1	0	0.175	0.175	0	P
C	IP-ND	ND	CBH	3200	3	0	2	0.175	0.175	0	P
C	IP-ND	IP	CBH	3200	3	1	0	0.175	0.175	0	P
C	IP-ND	ND	CBH	3200	4	0	2	0.195	0.195	0	P
C	IP-ND	IP	CBH	3200	4	1	0	0.195	0.195	0	P
C	IP-ND	ND	CBH	3200	5	0	2	0.24	0.24	0	P
C	IP-ND	IP	CBH	3200	5	1	0	0.24	0.24	0	P
C	ND-IP	ND	CBH	3200	6	0	1	0.21	0.21	0	P
C	ND-IP	IP	CBH	3200	6	2	0	0.21	0.21	0	P
C	ND-IP	ND	CBH	3200	7	0	1	0.255	0.255	0	P
C	ND-IP	IP	CBH	3200	7	2	0	0.255	0.255	0	P
C	ND-IP	ND	CBH	3200	8	0	1	0.255	0.215	0.04	P
C	ND-IP	IP	CBH	3200	8	2	0	0.215	0.215	0	P
C	ND-IP	IP	CBH	3200	8	2	0	0.205	0.205	0	P
C	ND-IP	ND	CBH	3200	9	0	1	0.22	0.205	0.015	P
C	ND-IP	ND	CBH	3200	10	0	1	0.24	0.24	0	P
C	ND-IP	IP	CBH	3200	10	2	0	0.24	0.24	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
D	IP-ND	ND	PWB	3170	1	0	2	0.2	0.185	0.015	P
D	IP-ND	IP	PWB	3170	1	1	0	0.25	0.2	0.05	P
D	IP-ND	ND	PWB	3170	2	0	2	0.25	0.225	0.025	P
D	IP-ND	IP	PWB	3170	2	1	0	0.275	0.25	0.025	P
D	IP-ND	ND	PWB	3170	3	0	2	0.21	0.21	0	P
D	IP-ND	IP	PWB	3170	3	1	0	0.275	0.21	0.065	C
D	IP-ND	ND	PWB	3170	4	0	2	0.205	0.205	0	P
D	IP-ND	IP	PWB	3170	4	1	0	0.275	0.205	0.07	C
D	IP-ND	ND	PWB	3170	5	0	2	0.225	0.19	0.035	P
D	IP-ND	IP	PWB	3170	5	1	0	0.275	0.225	0.05	P
D	ND-IP	ND	PWB	3170	6	0	1	0.245	0.205	0.04	P
D	ND-IP	IP	PWB	3170	6	2	0	0.205	0.205	0	P
D	ND-IP	ND	PWB	3170	7	0	1	0.255	0.2	0.055	P
D	ND-IP	IP	PWB	3170	7	2	0	0.2	0.2	0	P
D	ND-IP	ND	PWB	3170	8	0	1	0.235	0.235	0	P
D	ND-IP	IP	PWB	3170	8	2	0	0.235	0.235	0	P
D	ND-IP	ND	PWB	3170	9	0	1	0.21	0.195	0.015	P
D	ND-IP	IP	PWB	3170	9	2	0	0.195	0.195	0	P
D	ND-IP	ND	PWB	3170	10	0	1	0.23	0.2	0.03	P
D	ND-IP	IP	PWB	3170	10	2	0	0.2	0.2	0	P
E	IP-ND	ND	PWB	3170	1	0	2	0.175	0.175	0	P
E	IP-ND	IP	PWB	3170	1	1	0	0.175	0.175	0	P
E	IP-ND	ND	PWB	3170	2	0	2	0.21	0.21	0	P
E	IP-ND	IP	PWB	3170	2	1	0	0.21	0.21	0	P
E	IP-ND	ND	PWB	3170	3	0	2	0.195	0.195	0	P
E	IP-ND	IP	PWB	3170	3	1	0	0.195	0.195	0	P
E	IP-ND	ND	PWB	3170	4	0	2	0.185	0.185	0	P
E	IP-ND	IP	PWB	3170	4	1	0	0.185	0.185	0	P
E	IP-ND	ND	PWB	3170	5	0	2	0.155	0.155	0	P
E	IP-ND	IP	PWB	3170	5	1	0	0.155	0.155	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
E	ND-IP	ND	PWB	3170	6	0	1	0.225	0.21	0.015	P
E	ND-IP	IP	PWB	3170	6	2	0	0.21	0.21	0	P
E	ND-IP	ND	PWB	3170	7	0	1	0.225	0.2	0.025	P
E	ND-IP	IP	PWB	3170	7	2	0	0.2	0.2	0	P
E	ND-IP	ND	PWB	3170	8	0	1	0.175	0.175	0	P
E	ND-IP	IP	PWB	3170	8	2	0	0.175	0.175	0	P
E	ND-IP	ND	PWB	3170	9	0	1	0.19	0.17	0.02	P
E	ND-IP	IP	PWB	3170	9	2	0	0.17	0.17	0	P
E	ND-IP	ND	PWB	3170	10	0	1	0.2	0.185	0.015	P
E	ND-IP	IP	PWB	3170	10	2	0	0.185	0.185	0	P
F	IP-ND	ND	PWB	3170	1	0	2	0.21	0.2	0.01	P
F	IP-ND	IP	PWB	3170	1	1	0	0.215	0.21	0.005	P
F	IP-ND	ND	PWB	3170	2	0	2	0.21	0.21	0	P
F	IP-ND	IP	PWB	3170	2	1	0	0.215	0.21	0.005	P
F	IP-ND	ND	PWB	3170	3	0	2	0.205	0.185	0.02	P
F	IP-ND	IP	PWB	3170	3	1	0	0.225	0.205	0.02	P
F	IP-ND	ND	PWB	3170	4	0	2	0.195	0.195	0	P
F	IP-ND	IP	PWB	3170	4	1	0	0.225	0.195	0.03	P
F	IP-ND	ND	PWB	3170	5	0	2	0.2	0.2	0	P
F	IP-ND	IP	PWB	3170	5	1	0	0.25	0.2	0.05	P
F	ND-IP	ND	PWB	3170	6	0	1	0.215	0.175	0.04	P
F	ND-IP	IP	PWB	3170	6	2	0	0.175	0.175	0	P
F	ND-IP	ND	PWB	3170	7	0	1	0.21	0.195	0.015	P
F	ND-IP	IP	PWB	3170	7	2	0	0.195	0.195	0	P
F	ND-IP	ND	PWB	3170	8	0	1	0.21	0.21	0	P
F	ND-IP	IP	PWB	3170	8	2	0	0.21	0.21	0	P
F	ND-IP	ND	PWB	3170	9	0	1	0.22	0.21	0.01	P
F	ND-IP	IP	PWB	3170	9	2	0	0.21	0.21	0	P
F	ND-IP	ND	PWB	3170	10	0	1	0.21	0.19	0.02	P
F	ND-IP	IP	PWB	3170	10	2	0	0.19	0.19	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
G	IP-ND	ND	PWB	3170	6	0	2	0.185	0.185	0	P
G	IP-ND	IP	PWB	3170	6	1	0	0.2	0.185	0.015	P
G	IP-ND	ND	PWB	3170	7	0	2	0.19	0.18	0.01	P
G	IP-ND	IP	PWB	3170	7	1	0	0.2	0.19	0.01	P
G	IP-ND	ND	PWB	3170	8	0	2	0.195	0.19	0.005	P
G	IP-ND	IP	PWB	3170	8	1	0	0.2	0.195	0.005	P
G	IP-ND	ND	PWB	3170	9	0	2	0.185	0.185	0	P
G	IP-ND	IP	PWB	3170	9	1	0	0.2	0.185	0.015	P
G	IP-ND	ND	PWB	3170	10	0	2	0.22	0.22	0	P
G	IP-ND	IP	PWB	3170	10	1	0	0.22	0.22	0	P
G	ND-IP	ND	PWB	3170	1	0	1	0.2	0.19	0.01	P
G	ND-IP	IP	PWB	3170	1	2	0	0.19	0.19	0	P
G	ND-IP	ND	PWB	3170	2	0	1	0.25	0.225	0.025	P
G	ND-IP	IP	PWB	3170	2	2	0	0.225	0.21	0.015	P
G	ND-IP	ND	PWB	3170	3	0	1	0.27	0.165	0.105	P
G	ND-IP	IP	PWB	3170	3	2	0	0.165	0.165	0	P
G	ND-IP	ND	PWB	3170	4	0	1	0.215	0.19	0.025	P
G	ND-IP	IP	PWB	3170	4	2	0	0.19	0.175	0.015	P
G	ND-IP	ND	PWB	3170	5	0	1	0.24	0.175	0.065	P
G	ND-IP	IP	PWB	3170	5	2	0	0.175	0.175	0	P
H	IP-ND	ND	PWB	3170	6	0	2	0.2	0.165	0.035	P
H	IP-ND	IP	PWB	3170	6	1	0	0.2	0.2	0	P
H	IP-ND	ND	PWB	3170	7	0	2	0.18	0.17	0.01	P
H	IP-ND	IP	PWB	3170	7	1	0	0.18	0.18	0	P
H	IP-ND	ND	PWB	3170	8	0	2	0.21	0.2	0.01	P
H	IP-ND	IP	PWB	3170	8	1	0	0.245	0.21	0.035	P
H	IP-ND	ND	PWB	3170	9	0	2	0.205	0.195	0.01	P
H	IP-ND	IP	PWB	3170	9	1	0	0.205	0.205	0	P
H	IP-ND	ND	PWB	3170	10	0	2	0.195	0.175	0.02	P
H	IP-ND	IP	PWB	3170	10	1	0	0.195	0.195	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
H	ND-IP	ND	PWB	3170	1	0	1	0.185	0.185	0	P
H	ND-IP	IP	PWB	3170	1	2	0	0.185	0.185	0	P
H	ND-IP	ND	PWB	3170	2	0	1	0.22	0.22	0	P
H	ND-IP	IP	PWB	3170	2	2	0	0.22	0.21	0.01	P
H	ND-IP	ND	PWB	3170	3	0	1	0.2	0.175	0.025	P
H	ND-IP	IP	PWB	3170	3	2	0	0.175	0.175	0	P
H	ND-IP	ND	PWB	3170	4	0	1	0.19	0.19	0	P
H	ND-IP	IP	PWB	3170	4	2	0	0.19	0.19	0	P
H	ND-IP	ND	PWB	3170	5	0	1	0.24	0.215	0.025	P
H	ND-IP	IP	PWB	3170	5	2	0	0.215	0.215	0	P
I	IP-ND	ND	PWB	3170	1	0	2	0.195	0.195	0	P
I	IP-ND	IP	PWB	3170	1	1	0	0.195	0.195	0	P
I	IP-ND	ND	PWB	3170	2	0	2	0.215	0.215	0	P
I	IP-ND	IP	PWB	3170	2	1	0	0.24	0.215	0.025	P
I	IP-ND	ND	PWB	3170	3	0	2	0.2	0.2	0	P
I	IP-ND	IP	PWB	3170	3	1	0	0.2	0.2	0	P
I	IP-ND	ND	PWB	3170	4	0	2	0.195	0.185	0.01	P
I	IP-ND	IP	PWB	3170	4	1	0	0.205	0.195	0.01	P
I	IP-ND	ND	PWB	3170	5	0	2	0.18	0.18	0	P
I	IP-ND	IP	PWB	3170	5	1	0	0.18	0.18	0	P
I	ND-IP	ND	PWB	3170	6	0	1	0.235	0.225	0.01	P
I	ND-IP	IP	PWB	3170	6	2	0	0.225	0.225	0	P
I	ND-IP	ND	PWB	3170	7	0	1	0.19	0.175	0.015	P
I	ND-IP	IP	PWB	3170	7	2	0	0.175	0.175	0	P
I	ND-IP	ND	PWB	3170	8	0	1	0.23	0.21	0.02	P
I	ND-IP	IP	PWB	3170	8	2	0	0.21	0.21	0	P
I	ND-IP	ND	PWB	3170	9	0	1	0.195	0.19	0.005	P
I	ND-IP	IP	PWB	3170	9	2	0	0.19	0.19	0	P
I	ND-IP	ND	PWB	3170	10	0	1	0.175	0.175	0	P
I	ND-IP	IP	PWB	3170	10	2	0	0.175	0.175	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
J	IP-ND	ND	CCM	3276	1	0	2	0.125	0	0.125	F
J	IP-ND	IP	CCM	3276	1	1	0	0.125	0.125	0	P
J	IP-ND	ND	CCM	3276	2	0	2	0.09	0	0.09	F
J	IP-ND	IP	CCM	3276	2	1	0	0.125	0.09	0.035	P
J	IP-ND	ND	CCM	3276	3	0	2	0.105	0	0.105	F
J	IP-ND	IP	CCM	3276	3	1	0	0.15	0.105	0.045	P
J	IP-ND	ND	CCM	3276	4	0	2	0.12	0	0.12	F
J	IP-ND	IP	CCM	3276	4	1	0	0.125	0.12	0.005	P
J	IP-ND	ND	CCM	3276	5	0	2	0.11	0	0.11	F
J	IP-ND	IP	CCM	3276	5	1	0	0.135	0.11	0.025	P
J	ND-IP	ND	CCM	3276	6	0	1	0.15	0	0.15	F
J	ND-IP	ND	CCM	3276	7	0	1	0.125	0	0.125	F
J	ND-IP	ND	CCM	3276	8	0	1	0.14	0	0.14	F
J	ND-IP	ND	CCM	3276	9	0	1	0.13	0	0.13	F
J	ND-IP	ND	CCM	3276	10	0	1	0.125	0	0.125	F
K	IP-ND	ND	CCM	3276	1	0	2	0.11	0	0.11	F
K	IP-ND	IP	CCM	3276	1	1	0	0.125	0.11	0.015	P
K	IP-ND	ND	CCM	3276	2	0	2	0.15	0	0.15	F
K	IP-ND	IP	CCM	3276	2	1	0	0.125	0.115	0.01	P
K	IP-ND	ND	CCM	3276	3	0	2	0.105	0	0.105	F
K	IP-ND	IP	CCM	3276	3	1	0	0.125	0.105	0.02	P
K	IP-ND	ND	CCM	3276	4	0	2	0.115	0	0.115	F
K	IP-ND	IP	CCM	3276	4	1	0	0.125	0.115	0.01	P
K	IP-ND	ND	CCM	3276	5	0	2	0.115	0	0.115	F
K	IP-ND	IP	CCM	3276	5	1	0	0.125	0.115	0.01	P
L	IP-ND	ND	CCM	3276	1	0	2	0.14	0	0.14	F
L	IP-ND	IP	CCM	3276	1	1	0	0.14	0.14	0	P
L	IP-ND	ND	CCM	3276	2	0	2	0.1	0	0.1	F
L	IP-ND	IP	CCM	3276	2	1	0	0.155	0.1	0.055	P
L	IP-ND	ND	CCM	3276	3	0	2	0.125	0	0.125	F
L	IP-ND	IP	CCM	3276	3	1	0	0.125	0.125	0	P
L	IP-ND	ND	CCM	3276	4	0	2	0.135	0	0.135	F
L	IP-ND	IP	CCM	3276	4	1	0	0.145	0.135	0.01	P
L	IP-ND	ND	CCM	3276	5	0	2	0.13	0	0.13	F
L	IP-ND	IP	CCM	3276	5	1	0	0.16	0.13	0.03	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
L	ND-IP	ND	CCM	3276	6	0	1	0.125	0	0.125	F
L	ND-IP	ND	CCM	3276	7	0	1	0.155	0	0.155	F
L	ND-IP	ND	CCM	3276	8	0	1	0.13	0	0.13	F
L	ND-IP	ND	CCM	3276	9	0	1	0.125	0	0.125	F
L	ND-IP	ND	CCM	3276	10	0	1	0.15	0	0.15	F
M	IP-ND	ND	BPB	3063	1	0	2	0.135	0.135	0	P
M	IP-ND	IP	BPB	3063	1	1	0	0.16	0.135	0.025	P
M	IP-ND	ND	BPB	3063	2	0	2	0.15	0.15	0	P
M	IP-ND	IP	BPB	3063	2	1	0	0.15	0.15	0	P
M	IP-ND	ND	BPB	3063	3	0	2	0.145	0.145	0	P
M	IP-ND	IP	BPB	3063	3	1	0	0.135	0.145	-0.01	P
M	IP-ND	ND	BPB	3063	4	0	2	0.155	0.155	0	P
M	IP-ND	IP	BPB	3063	4	1	0	0.135	0.155	-0.02	P
M	IP-ND	ND	BPB	3063	5	0	2	0.145	0.145	0	P
M	IP-ND	IP	BPB	3063	5	1	0	0.145	0.145	0	P
M	ND-IP	ND	BPB	3063	6	0	1	0.2	0.2	0	P
M	ND-IP	IP	BPB	3063	6	2	0	0.2	0.2	0	P
M	ND-IP	ND	BPB	3063	7	0	1	0.185	0.17	0.015	P
M	ND-IP	IP	BPB	3063	7	2	0	0.17	0.17	0	P
M	ND-IP	ND	BPB	3063	8	0	1	0.15	0.075	0.075	P
M	ND-IP	IP	BPB	3063	8	2	0	0.075	0.075	0	P
M	ND-IP	ND	BPB	3063	9	0	1	0.15	0.15	0	P
M	ND-IP	IP	BPB	3063	9	2	0	0.15	0.15	0	P
M	ND-IP	ND	BPB	3063	10	0	1	0.2	0.18	0.02	P
M	ND-IP	IP	BPB	3063	10	2	0	0.18	0.18	0	P
N	IP-ND	ND	BPB	3063	1	0	2	0.165	0.165	0	P
N	IP-ND	IP	BPB	3063	1	1	0	0.175	0.165	0.01	P
N	IP-ND	ND	BPB	3063	2	0	2	0.205	0.205	0	P
N	IP-ND	IP	BPB	3063	2	1	0	0.205	0.205	0	P
N	IP-ND	ND	BPB	3063	3	0	2	0.17	0.155	0.015	P
N	IP-ND	IP	BPB	3063	3	1	0	0.175	0.17	0.005	P
N	IP-ND	ND	BPB	3063	4	0	2	0.18	0.175	0.005	P
N	IP-ND	IP	BPB	3063	4	1	0	0.18	0.18	0	P
N	IP-ND	ND	BPB	3063	5	0	2	0.135	0.115	0.02	P
N	IP-ND	IP	BPB	3063	5	1	0	0.135	0.135	0	P

Code	Protocol	Test	Product	Lot	Tray	IP	ND	Orig Width	Post Width	Creep	P/F
N	ND-IP	ND	BPB	3063	6	0	1	0.25	0.205	0.045	P
N	ND-IP	IP	BPB	3063	6	2	0	0.205	0.205	0	P
N	ND-IP	ND	BPB	3063	7	0	1	0.22	0.215	0.005	P
N	ND-IP	IP	BPB	3063	7	2	0	0.215	0.215	0	P
N	ND-IP	ND	BPB	3063	8	0	1	0.225	0.225	0	P
N	ND-IP	IP	BPB	3063	8	2	0	0.225	0.22	0.005	P
N	ND-IP	ND	BPB	3063	9	0	1	0.215	0.205	0.01	P
N	ND-IP	IP	BPB	3063	9	2	0	0.205	0.205	0	P
N	ND-IP	ND	BPB	3063	10	0	1	0.21	0.2	0.01	P
N	ND-IP	IP	BPB	3063	10	2	0	0.2	0.2	0	P

COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION
User Manual
Non Destructive Seal Tester
For
Polymeric Trays

Technical Working Paper (TWP) 222

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Figure #1: Non Destructive Seal Tester for Polymeric Trays

1 Introduction

The Non Destructive Seal Tester (ND Tester) for Polymeric Trays is a prototype tester that was designed and constructed by the Industrial Engineering Department of Rutgers University. Development and validation of the test conditions was performed at the CORANET Demonstration Facility by the CAFT-FMT Staff.

The tester will exert a static compression force on the tray in order to generate a pressure inside the tray that is in balance with this external force. This internal pressure will also generate a force on the seal. Seals that are inadequate in strength will creep and eventually burst open.

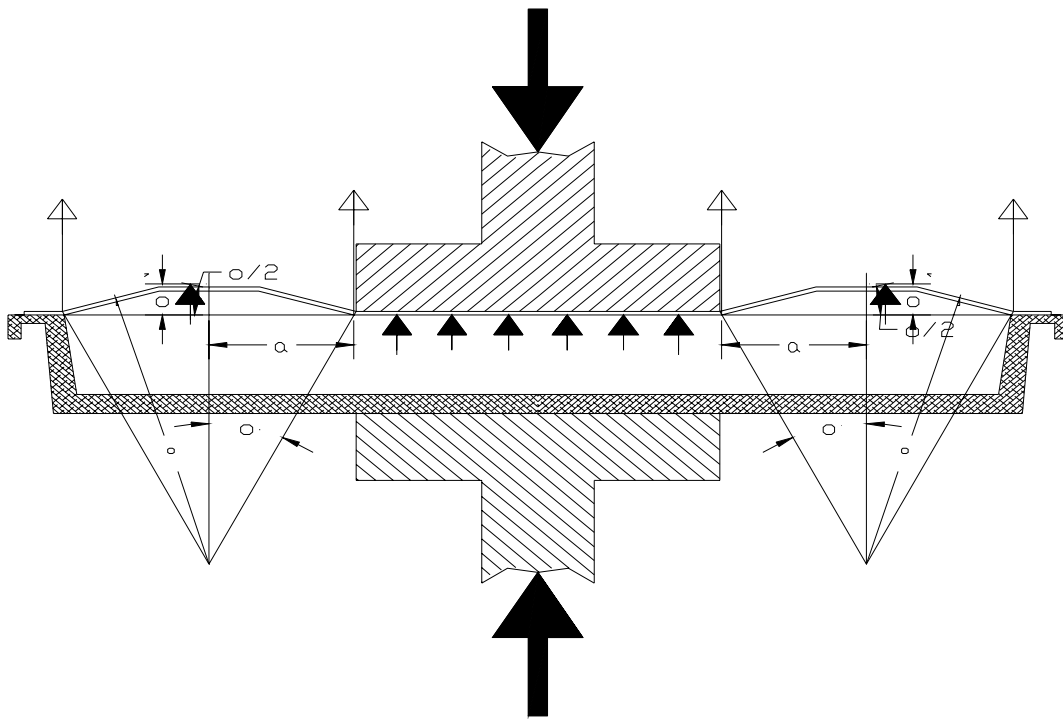


Figure 2: Force Diagram

The amount of energy stored inside the tray and in the pistons is significant and a catastrophic failure of the seal will result in a fair amount of product spillage. The tester has been equipped with a plexi-glass enclosure and with a membrane under the tray to minimize the area of contamination. Further protection from spillage can be achieved by double bagging the tray inside the 2.5 gal ziplock bags

2 Adjustment and Calibration of Tester

The following items need to be checked and adjusted as need

- 1) The supply pressure to the tester should be minimal 85 psig.
- 2) The incoming pressure to the pneumatic control system should be set at 80 psig. This pressure is directly applied to the down ward stroke of the top piston and locks it into the lowest position during the compression cycle.
- 3) Using the maintenance mode of the tester, extend the stroke of the top piston. This should place to the bottom of the top plate around 0.25" below the flange of the tray. If this creates a pressure inside the tray, 1/16" spacers to the top piston mounting lugs should be added till no pressure is created by the top plate
- 4) The pressure setting for bottom compression piston should be checked daily. The regulator for air supply to the upward stroke should be set at 60 psig. The regulator for air supply to the down ward stroke should be set at 10 psig.
- 5) The maximum stroke of the bottom piston can be adjusted by adding or removing spacer to the mounting lugs of the bottom piston (fig 3). It should be adjusted to the 1/8" more than the maximum compression stroke seen on any tray produced at the facility. The maximum compression stroke can be measured by running a test without a tray and should be recorded on a daily basis.

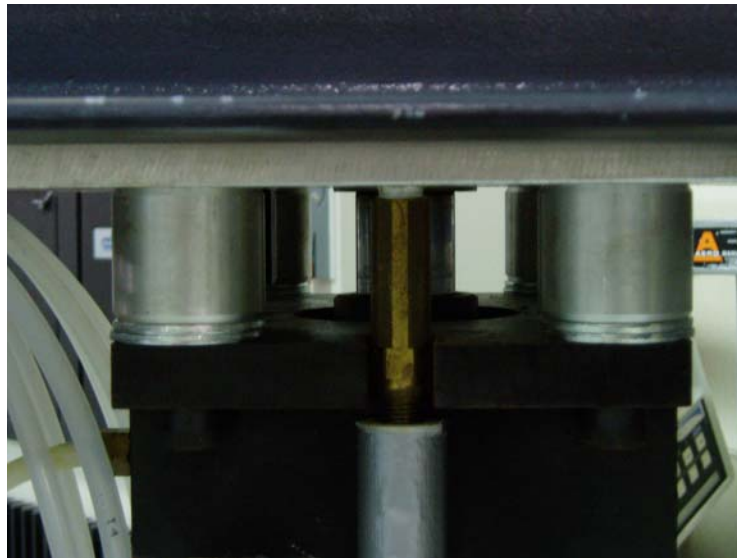


Figure 3: Adjustment Spacers for Maximum Compression Stroke

- 6) The software has the parameters can be adjusted. Recommended values are indicated in figure 4. Changes to this screen are saved automatically and used in subsequent tests

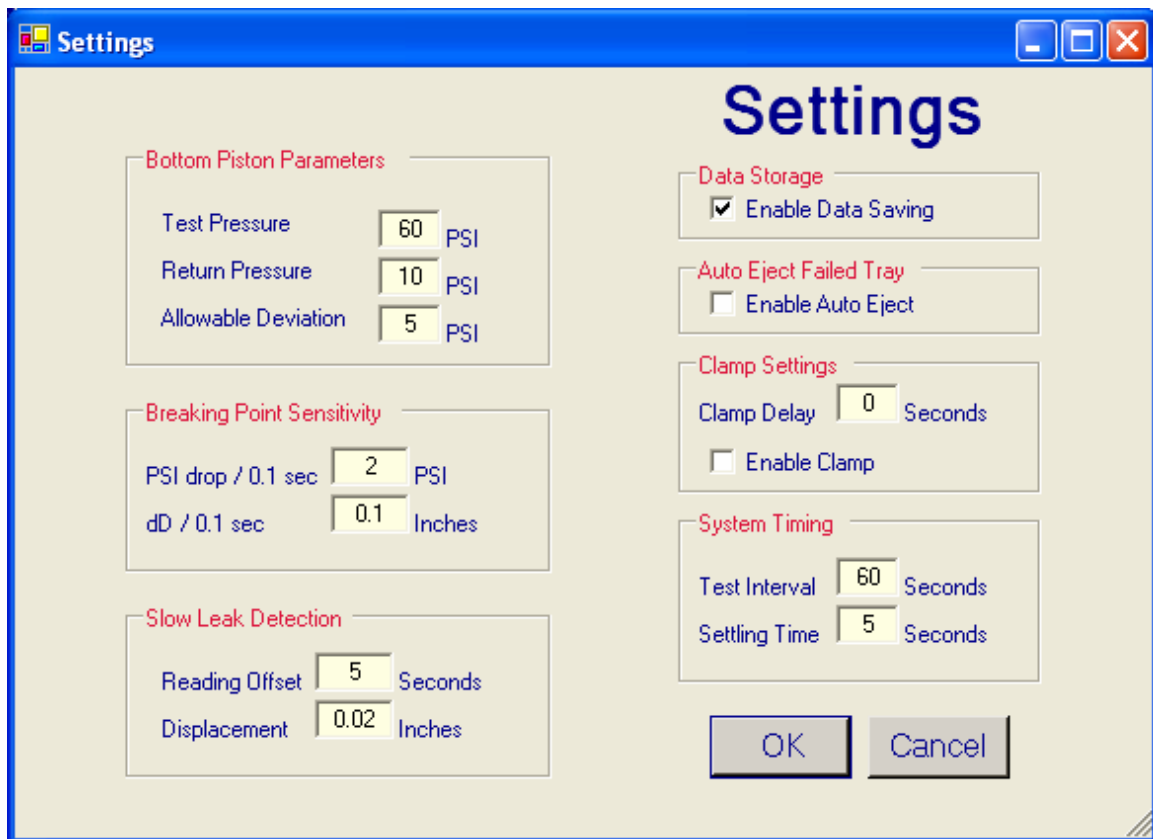


Figure 4: Adjustable Test Parameters

- a. Bottom Piston Parameters:
This section is used to set when the display will alarm if the values are out of tolerance
- b. Breaking Point Sensitivity
This section is used to set criteria when to abort the test in case of a catastrophic failure of the seal
- c. Slow Leak Detection
This section is used to set criteria when to abort the test in case of a small leak that is detected by the LVDT movement over a period of time. Displacement smaller than 0.02 are not recommended as it could lead to false positive rejects due to noise in the signal
- d. Data Storage
Not used
- e. Auto Eject Failed Tray
Not used
- f. Clamp Setting
Validation test were performed without use of the clamp
- g. System Timing
This section is used to set the total cycle time of the test and the settling time before calculations for breakpoint and slow leak start.

3 Operation

The tester is designed to test seal strength of trays filled with retorted material. It is not designed to test bakery products. The product needs to move hydraulically during the compression cycle in order to generate the appropriate seal forces. The following products have been tested successfully, without damage to the product: Cream Ground Beef, Potatoes with Bacon, White Rice, Corn Beef Hash, Hamburger patties in Brine, Pork Sausage in Brine, Chili with Beans, Apple Dessert, Buffalo Chicken, Sweet and Sour Pork, Red Beans, Chicken Breast.

To start the software, run “CPT.exe”

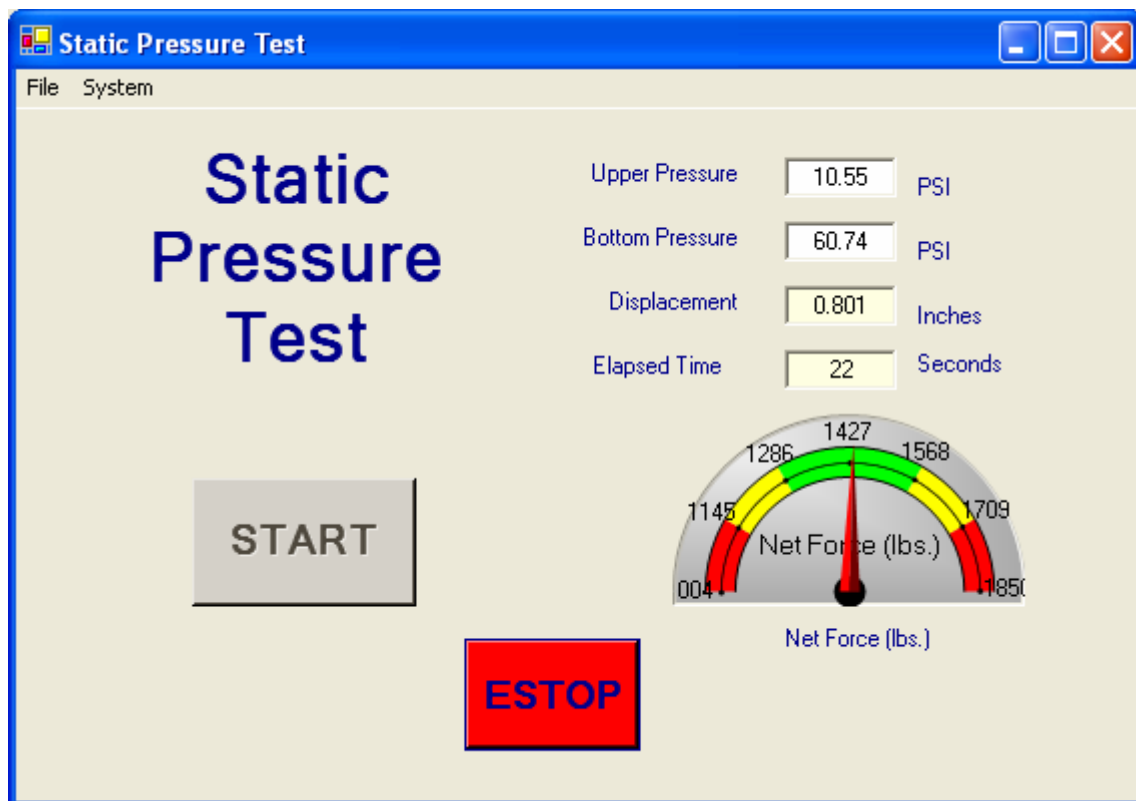


Figure 5: Main Test Screen

To start the test sequence click on the “Start” Button. To abort the test click on the “Estop” or push the “Emergency Stop” button in front of the tester.

Each day the tester should be run without a tray for the first test cycle to determine the maximum stroke of the bottom piston. The compression stroke during an actual test should be at least 1/8” less than this maximum stroke. The maximum stroke can be reduced or increased by adding or subtracting spacers to the bottom piston mounting lugs (fig 3)

Once the Start Button is clicked, all pistons will be retracted and the operator will be instructed to load the tray (figure 6).



Figure 6: Confirmation Tray Load Screen

Insert tray in tester and make sure that the tray is seated in the carrier with the flange properly seated.

It is recommended that the to-be tested tray is double bagged in a 2.5 gal zip lock bag that has vent holes. This will minimize the spillage if the seal fails catastrophically

Close the door and click the “OK” Button

The tester will automatically go through the compression test sequence

On the main screen the operator can follow the progress of the compression test (figure 5)

After the timer has reached 60 seconds, the test will terminate by retracting the bottom piston and indicating to the operator that the tester tray passed (figure 7). The operator has the option to save the force data to a file for diagnostic reasons (figure 8). To eject the tray, the operator should click on the “OK” button.

“Tray Passed” indicates that the tester did not detect a catastrophic failure or small leak. It does not mean that the tray passed.

A visual inspection of the tray and seal is required after the test, to determine that no small leak occurred what the minimal seal width of the tray is. Compare this to the specification limits set for this test to determine if the tray passed or failed the test.



Figure 7: Test Complete Screen

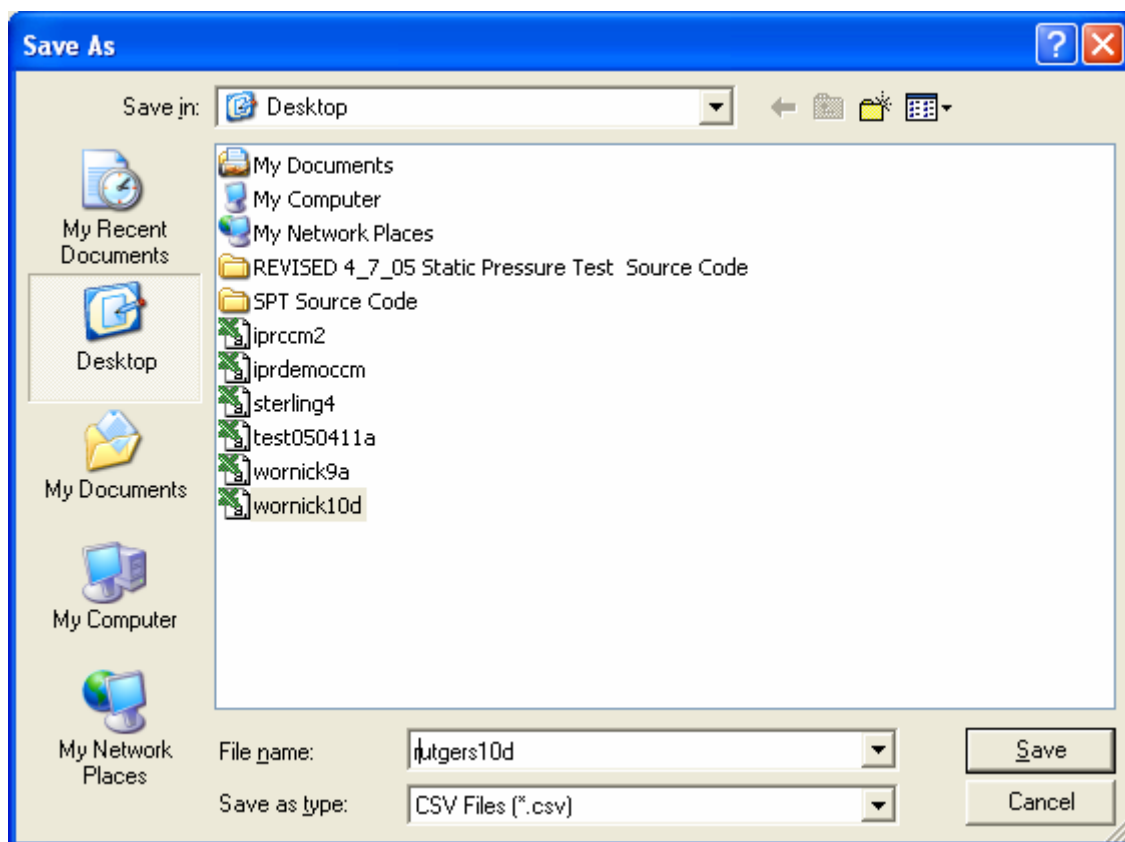


Figure 8: Save File Screen

If the tester detects movement in the bottom compression plate, it will interpret this as a small leak and terminate the test. If the tester detects a sudden drop in compression pressure and/or detects a rapid movement in the compression plate it will interpret this as a catastrophic seal failure and terminate the test immediately. In both cases the operator will be told that the tray failed and the reason of failure.



Figure 9: Test Abort Screen

It is recommended that the operator cleans the test area before clicking on the "OK" button to eject the tray.

After the top plate is fully retracted, the operator will be asked to confirm that the bottom plate can be raised to eject the tray (figure 10). This gives the operator a final opportunity to clean the area and avoid that product spills in the tray cavity.



Figure 10: Eject Tray Screen

4 Maintenance

The ND tester has a maintenance mode (figure 11) in which each piston can be controlled manually. This option can be accessed from the main screen under menu item “system”>”manual”

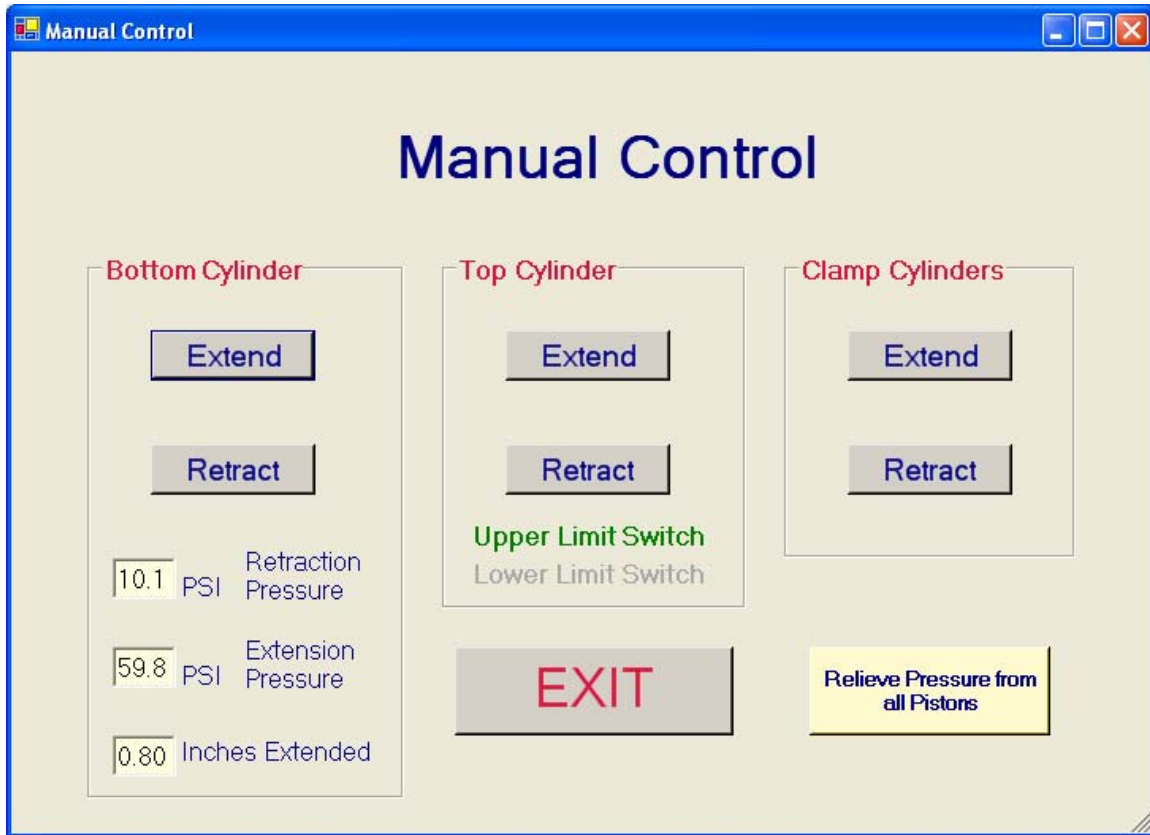


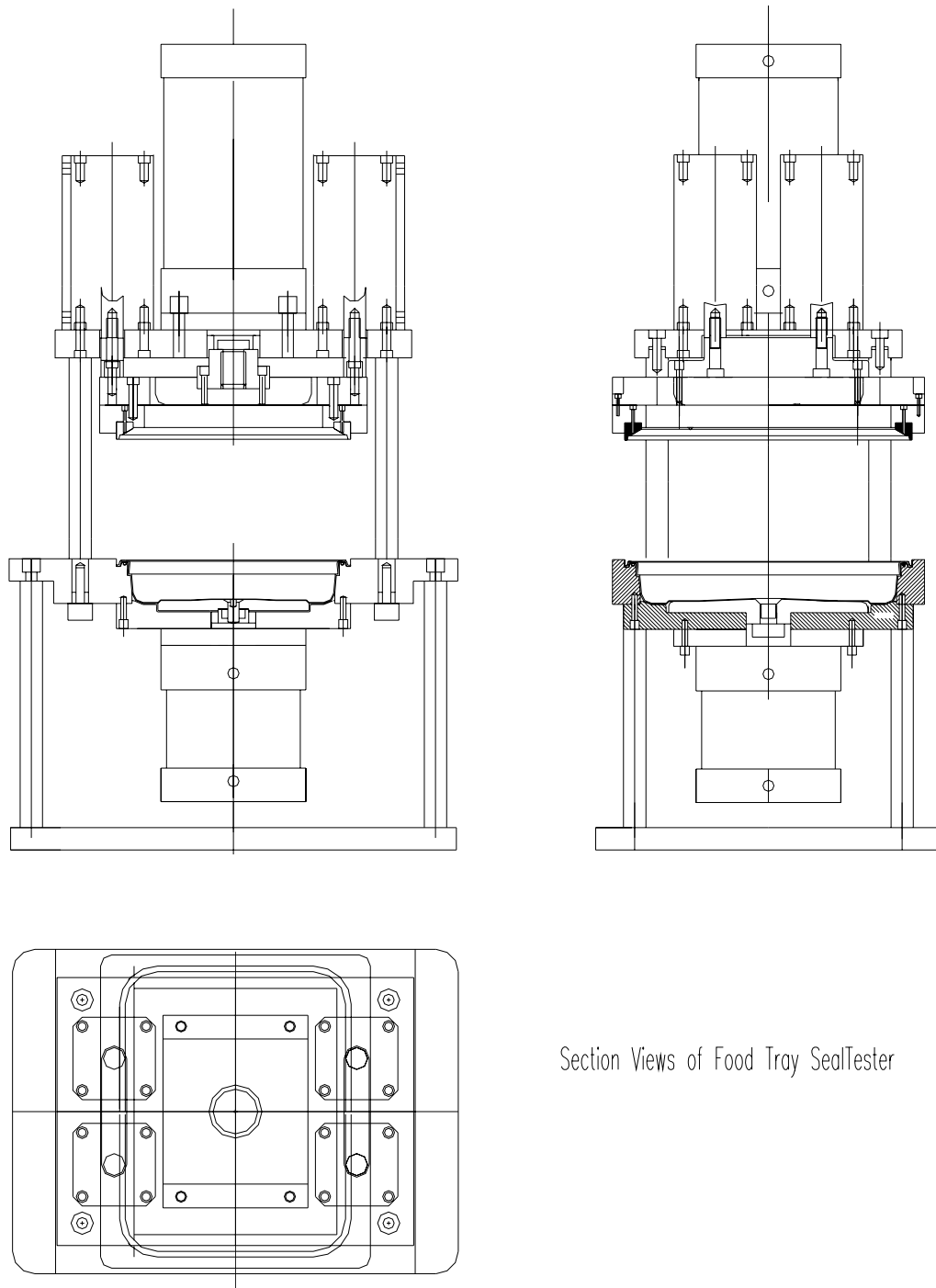
Figure 11: System Maintenance Screen

This mode can be used to maintain, lubricate and/or clean/sanitize the tester. It is recommended that:

- Lubrication of the pistons rods with a light oil once a month
- Clean and sanitize the tester after each spill
- Check the compression plates to make sure that they are free of foreign material.

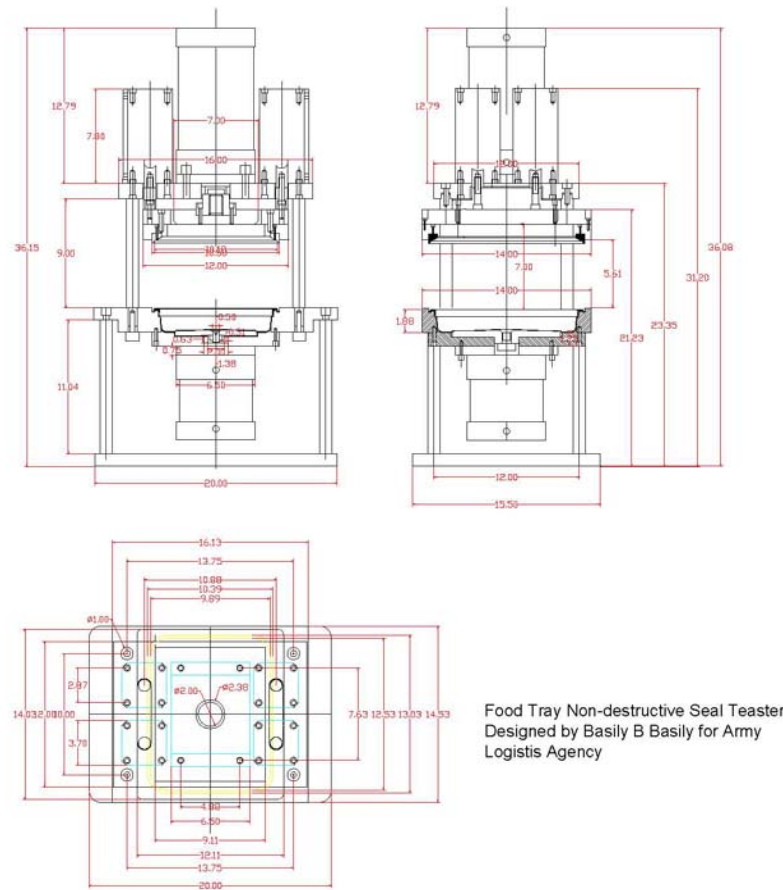
Foreign materials can damage the tray and lid.

5 Drawings



Section Views of Food Tray SealTester

**Figure 12: Section Views of the Food Tray Seal Tester
Designed by Basily B Basily**



Note
The top plate max. thickness is 1.25"
and the plate is held at 0.25" lower than the edge of the tray cavity

Figure 13: Dimensional Drawing ND Tester

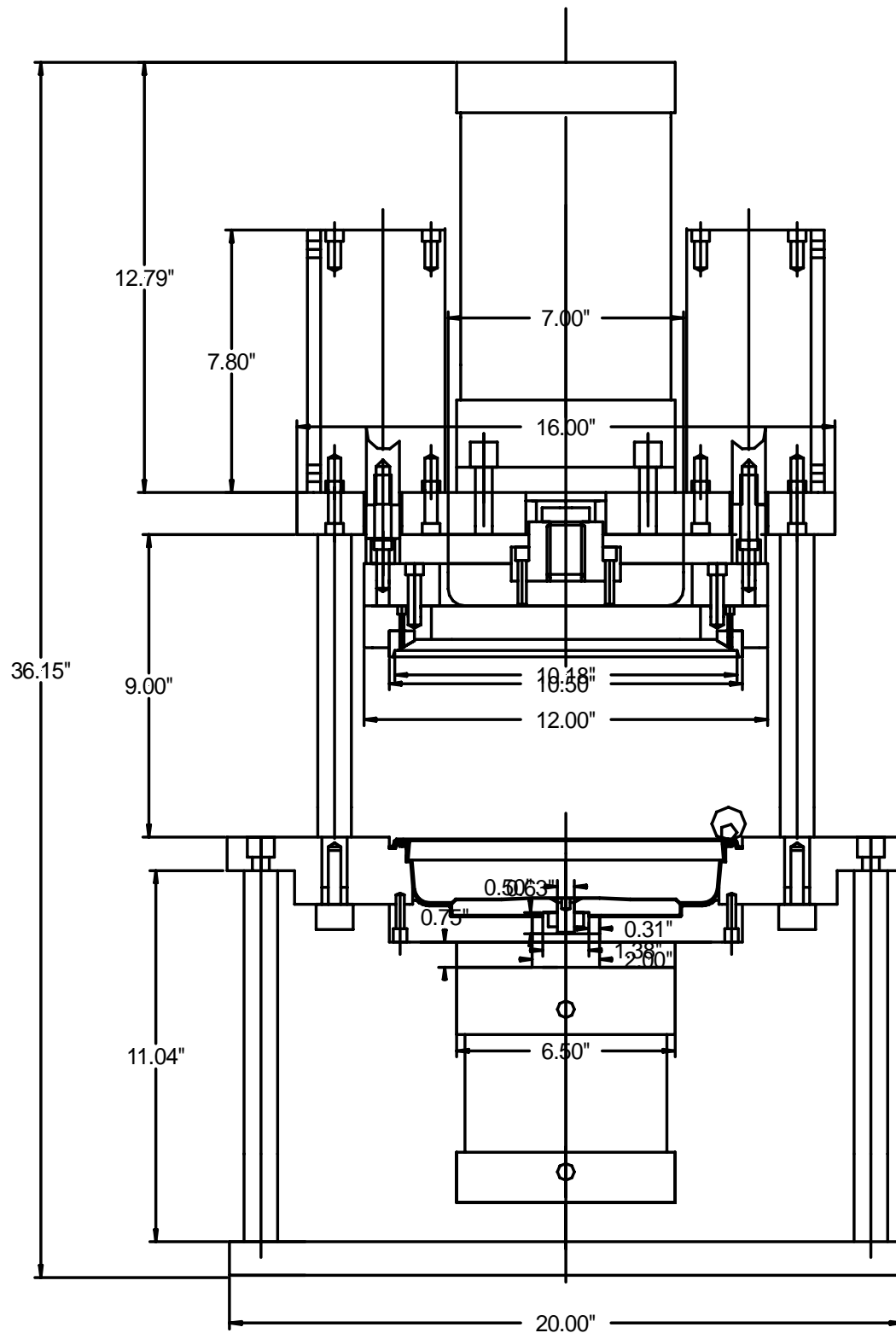


Figure 14: Front View Tester

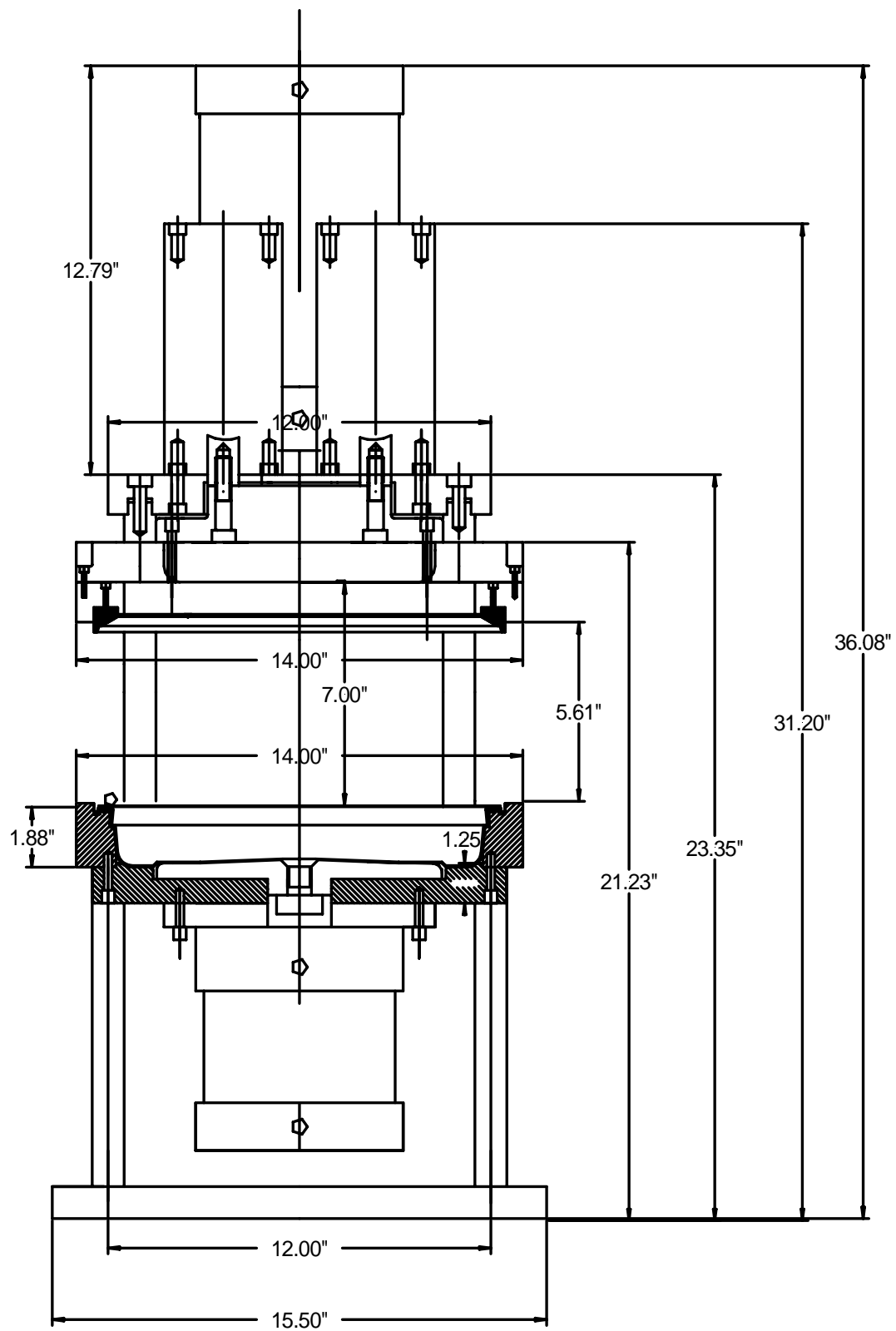


Figure 15: Side View Tester



6 Electrical Diagram

The following document lists all point-to-point wiring of the electrical box. Figure 17 references the chapter numbers with the physical location of the item in the electrical box.

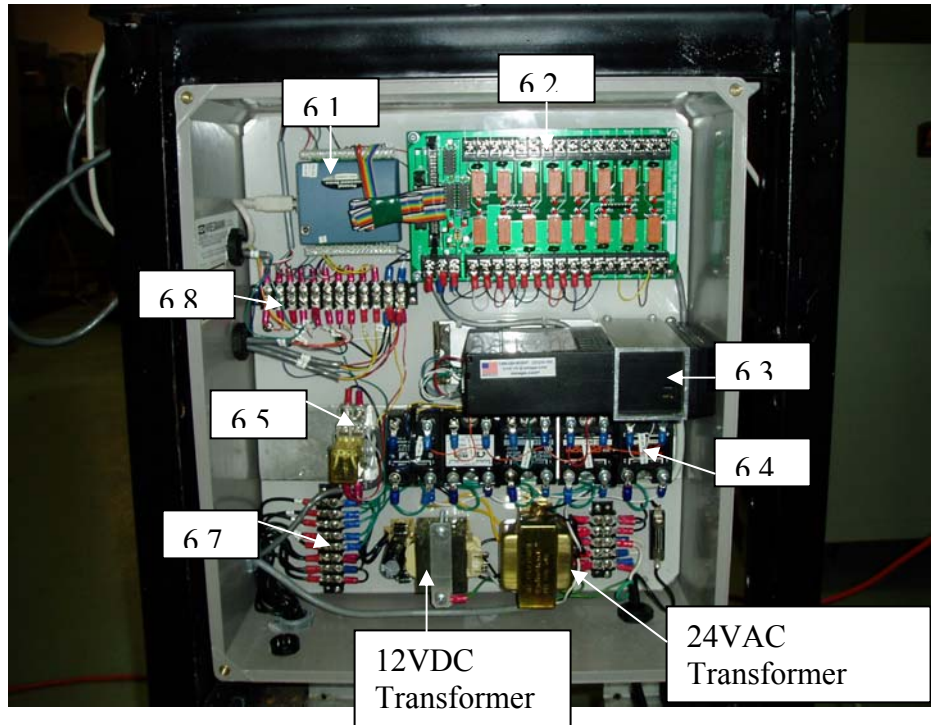


Figure 17: Electrical Box

6.1 PMD-1208LS Connections

Location: Upper left corner.

NOTE: The PMD-1208LS unit must be configured as Board #0 with 8 single ended analog inputs using the InstaCal Software.

- Pin 1 ►► Omega, Analog OUT, Volt, Pin 10*
- Pin 3 ►► Omega, Analog OUT, RTN, Pin 12*
- Pin 4 ►► Terminal Block 1, Upper Terminal 8
- Pin 5 ►► Terminal Block 1, Upper Terminal 9
- Pin 21 ►► Terminal Block 1, Upper Terminal 0
- Pin 22 ►► Terminal Block 1, Upper Terminal 1
- Pin 23 ►► Terminal Block 1, Upper Terminal 2
- Pin 24 ►► Terminal Block 1, Upper Terminal 3
- Pin 29 ►► Terminal Block 1, Upper Terminal 4
- Pin 30 ►► PCLD-885, CN3, Terminal 1

Pin 31 ► Terminal Block 1, Upper Terminal 10
Pin 32 ► PCLD-885, CN1, Pin 1 (Brown)
Pin 33 ► PCLD-885, CN1, Pin 2 (Red)
Pin 34 ► PCLD-885, CN1, Pin 3 (Orange)
Pin 35 ► PCLD-885, CN1, Pin 4 (Yellow)
Pin 36 ► PCLD-885, CN1, Pin 5 (Green)
Pin 37 ► PCLD-885, CN1, Pin 6 (Blue)
Pin 38 ► PCLD-885, CN1, Pin 7 (Purple)
Pin 39 ► PCLD-885, CN1, Pin 8 (White)

6.2 PCLD-885 Connections

Location: Upper right corner.

CN1 ► see PMD-1208LS connections for details

CN3

1	2	3
---	---	---

Terminal 1 ► PMD-1208LS, Pin 30
Terminal 2 ► Terminal Block 1, Upper Terminal 10
 ► Common to all SSR's at Terminal 4
Terminal 3 ► Terminal Block 1, Upper Terminal 11

CN4

CH0	CH1	CH2	CH3	CH4	CH5	CH6	CH7
A B	A B	A B	A B	A B	A B	A B	A B

Terminals B of **all channels** are wired to Terminal 3 of CN3 on this board(PCLD-885).

Terminals A of all channels go to the SSR's as follows:

CH0 A ► Relay 0, Terminal 3
CH1 A ► Relay 1, Terminal 3
CH2 A ► Relay 2, Terminal 3
CH3 A ► Relay 3, Terminal 3
CH4 A ► Relay 4, Terminal 3

6.3 OMEGA LVDT Driver

Location: Center swing out module.

Signal Wires

Analog OUT, Volt, Pin 10*	► PMD-1208LS, Pin 1
Analog OUT, RTN, Pin 12*	► PMD-1208LS, Pin 3
TB2, -E OUT (1*)	► Terminal Block 1, Upper Terminal 6
TB2, +E OUT (2*)	► Terminal Block 1, Upper Terminal 7
TB2, +S IN (6*)	► Terminal Block 1, Upper Terminal 5
TB2, -S IN (7*)	► (JUMPER) TB2, -E OUT (1*)

6.4 Solid State Relays (SSR's)

Location: Below the Omega driver.

NOTE: Relays are numbered from RIGHT to LEFT, starting with 0.

Terminal 1 of all SSR's is common to 24VAC Transformer

Terminal 4 of all SSR's is common to 12VDC GROUND at PCLD-885, CN3, Terminal 2.

The following chart shows the rest of the SSR connections:

SSR #0, Terminal 2 ► Terminal Block 2, Right Side Terminal 0
Terminal 3 ► PCLD-885, CH0 A

SSR #1, Terminal 2 ► Terminal Block 2, Right Side Terminal 1
Terminal 3 ► PCLD-885, CH1 A

SSR #2, Terminal 2 ► Terminal Block 2, Right Side Terminal 2
SSR #2, Terminal 3 ► PCLD-885, CH2 A

SSR #3, Terminal 2 ► Terminal Block 2, Right Side Terminal 3
SSR #3, Terminal 3 ► PCLD-885, CH3 A

SSR #4, Terminal 2 ► Terminal Block 2, Right Side Terminal 4
SSR #4, Terminal 3 ► PCLD-885, CH4 A

6.5 ESTOP Relay

Location: Single mechanical relay (yellow) left of the SSR bank.

- Pin 5 ► Terminal Block 1, Lower Terminal 3
- Pin 8 ► 24VAC Transformer
- Pin 9 ► Terminal Block 1, Lower Terminal 4
- Pin 12 ► Terminal Block 2, Right Side, Terminals 5,6,7
- Pin 13 ► ESTOP Switch, Terminal 1 (White)
- Pin 14 ► Terminal Block 1, Lower Terminal 11

6.6 ESTOP Switch

Location: Located outside the electrical box.

- Terminal 1 ► ESTOP Relay, Pin 13
- Terminal 2 ► Terminal Block 1, Lower Terminal 10
- Terminal 3 ► (JUMPER) Bulb B
- Terminal 4 ► 110VAC
- Bulb A ► 110VAC
- Bulb B ► (JUMPER) Terminal 3

6.7 Terminal Block 2

Location: Lower left corner of electrical box.

NOTE: Terminals numbered from TOP to BOTTOM, starting with 0.

Left Side Connections

Terminal #

- 0 ► Solenoid #3 (Retract Top Piston)
- 1 ► Solenoid #2 (Retract Clamp)
- 2 ► Solenoid #5 (Bottom Piston, Dump Valve)
- 3 ► Solenoid #4 (Extend Top Piston)
- 4 ► Solenoid #1 (Extend Clamp)
- 5 ► Solenoid GROUND
- 6 ► Solenoid GROUND
- 7 ► Solenoid GROUND

Right Side Connections

Terminal #

- 0 ► SSR #0, Terminal 2
- 1 ► SSR #1, Terminal 2
- 2 ► SSR #2, Terminal 2
- 3 ► SSR #3, Terminal 2
- 4 ► SSR #4, Terminal 2
- 5 ► ESTOP Relay, Pin 12
- 6 ► ESTOP Relay, Pin 12
- 7 ► ESTOP Relay, Pin 12

6.8 Terminal Block 1

Location: Left side of electrical box, below PMD-1208LS

NOTE: Terminals numbered from LEFT to RIGHT, starting with 0.

UPPER Connections

Terminal

- 0 ► PMD-1208LS, Pin 21
- 1 ► PMD-1208LS, Pin 22
- 2 ► PMD-1208LS, Pin 23
- 3 ► PMD-1208LS, Pin 24
- 4 ► PMD-1208LS, Pin 29
- 5 ► OMEGA, TB2, +S IN (6*)
- 6 ► OMEGA, TB2, -E OUT (1*)
- 7 ► OMEGA, TB2, +E OUT (2*)
- 8 ► PMD-1208LS, Pin 4
- 9 ► PMD-1208LS, Pin 5
- 10 ► PMD-1208LS, Pin 31
 - PCLD-885, CN3, Terminal 2
- 11 ► PCLD-885, CN3, Terminal 3

LOWER Connections

Terminal

- 0 ► Limit Switch, Top Piston, Bottom switch, (NO), (Orange)
- 1 ► Limit Switch, Top Piston, Top switch, (NO), (Yellow)
- 2 ► Limit Switch, Front Door, (NO), (Blue)
- 3 ► ESTOP Relay, Pin 5, (Blue)
- 4 ► Limit Switch Common for Top Piston and Door
 - ESTOP Relay, Pin 9
- 5 ► Signal from LDVT (Orange)
- 6 ► Ground for LDVT **ONLY!** (Black) **ISOLATED!!!!**
- 7 ► + Power for LDVT **ONLY!** (Red)
- 8 ► Signal from Pressure Transducer, 60psi side, (Yellow)
- 9 ► Signal from Pressure Transducer, 10psi side, (Yellow)
- 10 ► 12VDC Ground at power supply
 - Power ground for Pressure Transducers
 - ESTOP Switch, Pin 2 (Yellow)
- 11 ► +12VDC at power supply
 - +12VDC for Pressure Transducers
 - ESTOP Relay, Pin 14

7 Pneumatic Diagram

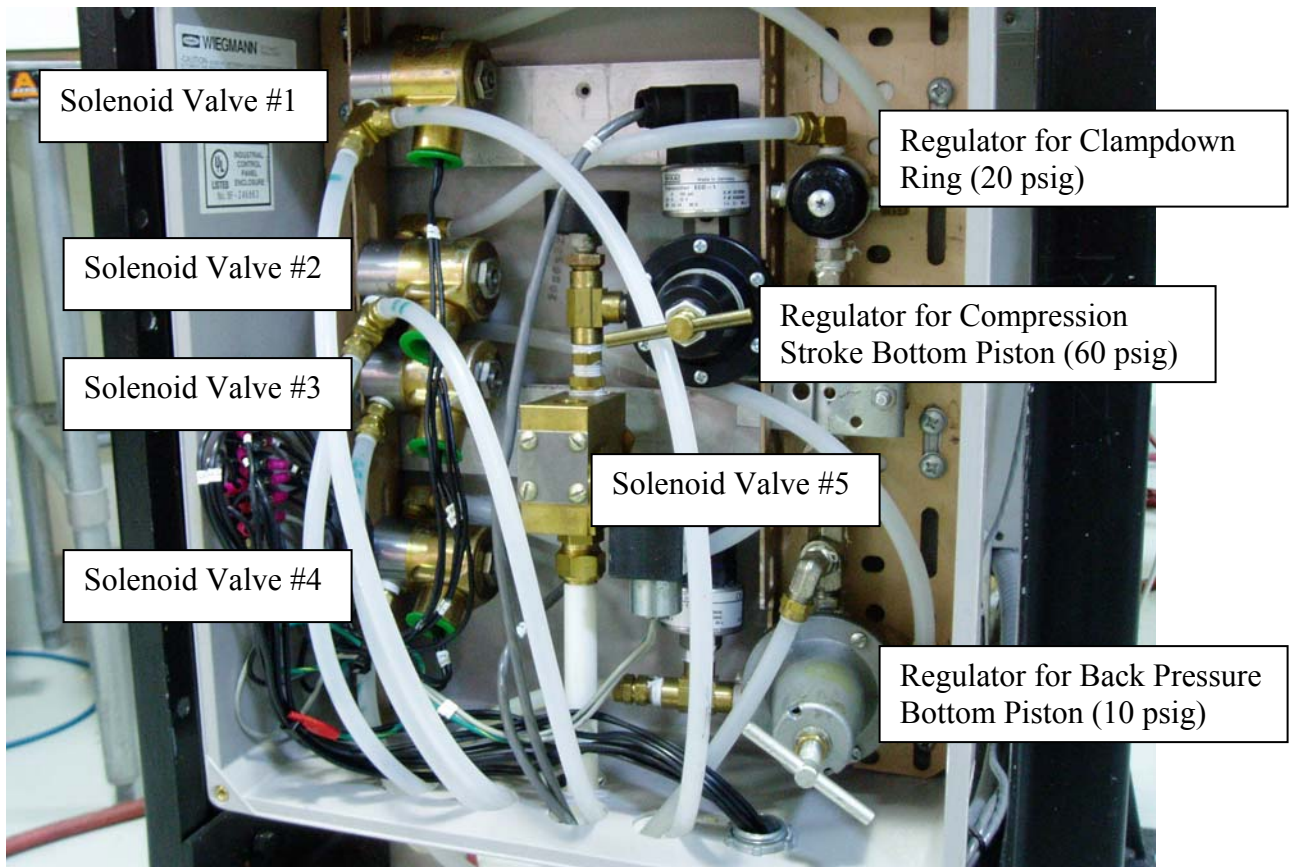
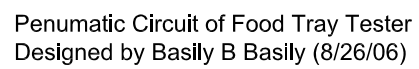


Figure 18: Pneumatic Box



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8 Parts List

NAME	VENDOR_PART_NUMBER	QTY
MEASUREMENT COMPUTING	Personal Measurement Device for USB, 2 D/A outputs, 16 DIO, Product No. PMD-1208LS	1
ADVANTECH USA	16 Channel Power Relay Output Board, Model PCLD-885	1
MCMaster-CARR SUPPLY CO.	# (49085K73) 24 VAC Quick exhaust 3-way valve, 3/8 pipe size	1
MCMaster-CARR SUPPLY CO.	8789K13, 12"x24" 1/16" thick, (40A Durometer) polyurethane	1
MCMaster-CARR SUPPLY CO.	8789K23, 12"x24" 1/8" thick, (40A Durometer), polyurethane	1
MSC DIRECT, INC	Cylinder (Norgen # EJ0375D1/ 6" bore and 7.0" stroke)	1
MSC DIRECT, INC	Cylinder (Norgen # EJ0375C3/ 6" bore and 2.0" stroke)	1
MSC DIRECT, INC	Cylinder (Norgen # DC92080/M6" stroke)	4
MSC DIRECT, INC	Pressure Transmitter #56460017	2
OMEGA	LP804-03 Pot Displacement Sensor 3 inch.	1
OMEGA	Signal Conditioner, model DP25B-E-A	1

Validation Protocol for the Non Destructive Seal Strength Tester
Version 1.03 (5/18/06)

This is a working document to develop proposed validation protocol for the Non Destructive Seal Strength Tester (STP#2016), also referred to as the **ND Tester**

The ND Tester can be used for two applications in the poly tray production system.

- 1) Replacement of the Internal Pressure Test for Lot Acceptability Testing
- 2) Quantification of strength of Seals that have Anomalies

Each application area will have its own validation protocol

Replacement of the Internal Pressure Test for Lot Acceptability

The primary purpose of the ND tester, is to replace the current destructive Internal Pressure Test for finished product lot inspection. There are two issues with the Internal Pressure test:

- the IP test is destructive so the tray can not be added back to the lot..
- the IP test is not reliable in detecting weak seals, because the forces generated on the seal are inadequate to detect partial non fusion seals.

The ND tester generates approximately the same internal pressure as the destructive test, but the geometry of the lid-stock near the seal generates higher peel forces on the seal and thus able to detect more reliable non fusion seals.

The following test protocol is being proposed:

- Inspect the seal width prior to the test. If the seal width is less than 1/8" select another tray (**Rationale is that seal width is examined separately, There shouldn't be the possibility of double jeopardy).
- If the minimum seal width is equal or more than 1/8", test the tray in the non destructive seal strength tester. Compress the tray with two plates, the top plate outer perimeter is 1" within the flange of the tray allowing the lid stock to bulge up and strain the seal. The bottom plate is shaped according to the oval indentation of the bottom of the tray. Apply a compression force of 1400 lbf. on to the tray and hold this for 60 seconds.
- After the test remove the tray from the tester and re-inspect the seal. If the minimum seal width yielded to less than 1/16", reject the tray. ~~If the minimum seal width after testing yielded by less than 1/16" or if~~ the minimum seal width is 1/16" or more, the tray passes.

Validation of the Test Protocol

Objective: Validate that the ND tester is equal to better than the IP tester to detect weak/non fusion seals

To validate the tester as a replacement for the destructive IP tester, we propose a two step validation protocol.

First: we will test 70 trays via the destructive internal pressure tester (5 tray samples from each lot). If the tray passes this test, the punctured hole in the lid-stock will be sealed with duct tape and the tray will be exposed to the ND test. Pass/Fail results in both tests will be recorded. Failed trays will be further inspected to determine the reason of failure (delamination, lid-stock failure, seal creep, open seal, etc.) and after peeling away the lid stock, the minimum width of the fusion seal will be recorded.

Second: we will test 70 trays first in the ND tester (5 tray samples from each lot). If the tray passes this test, the tray will be exposed to the IP test. Pass/Fail results of both tests will be recorded and again the seal of a failed tray will be further inspected to determine why the tray failed and to determine the minimum width of the fusion seal.

The following Test Data will be collected:

- Date:
- Product Name
- Lot Number
- Pass/Fail IP Test
- Reason Fail IP Test
- Pass/Fail ND Test
- Reason Fail ND Test
- Appearance of any Seal Anomalies before and after testing

Test results of the combined 140 tray sample set will be tabulated and statistically analyzed to confirm the hypothesis that the ND tester is equal or better in detecting weak seals than the IP tester. Once it is confirmed that the ND tester is as effective in detecting non fusion seals, the ND tester can be used as a replacement for the IP test.

Quantification of Seal Anomalies

- Lot acceptability testing requires visual inspection of 200 trays. The closure seal is one aspect that is evaluated during this test. The following is the definition of an acceptable closure seal. *“The closure seal, defined as the width of fusion bonded seal at any point perpendicular to the tray flange along the tray perimeter, shall be not less than 1/8 inch wide. The first 1/16 inch of the seal at the food product edge shall be free of defects or anomalies, such as, but not limited to entrapped matter, moisture or grease. The closure seal shall be continuous along the tray flange surface. The closure seal shall be free of impression or design on the seal surface and free of wrinkles.”*
- The closure seal is evaluated for:
 - Presence of entrapped matter within 1/16” of the food product edge of seal or entrapped moisture or vapor within 1/16” of the food product edge of seal that results in less than 1/16” of defect free seal width at the outside edge. **This type defect is critical unless the following is observed in which case the defect is scored as a minor:**
 - Small concave impressions or cavities indicating slight tray

imperfections or hard particulates affixed to the seal head and contacting the lid and tray.

- Small (i.e., 1/32 inch or less in any direction) convex bumps or points on the seal area indicating small imperfections on the seal head. NOTE: This anomaly is typically visible on successive trays coming off the heat sealer.
 - Minor impressions or scorching of the top layer of the lid material on the seal area indicating soft particulates on the seal head being “burned-off” during sealing. NOTE: This anomaly is typically visible on successive trays coming off the heat sealer.
 - Anomalies caused by entrapped moisture or vapor (which typically appear as concave spots on the tray flange surface) that result in less than 1/8” of defect free seal width at the outside edge of these spots.
- The above specification has resulted in many lots rejected, expensive rework and loss of product. The assignment of the defect into critical, major and minor categories is somewhat arbitrary and errs on the conservative side because there is no existing quick method to quantify the effect of the defect on the performance of the tray in regards of seal creep.
 - We propose the following test protocol for the ND-tester:
 - It is proposed that all critical (except open seals, non-continuous seals, cuts, holes and fold-over wrinkles) and major seal defects that are found during the visual seal examination are tested in the ND tester and that data is collected on the performance of the tray with this defect under the load of the tester.
 - Compress the tray in the ND tester between two plates, the top plate outer perimeter is 1” within the flange of the tray allowing the lid stock to bulge up and strain the seal. The bottom plate is shaped according to the oval indentation of the bottom of the tray. Apply a compression force of 1400 lbf. on the tray and hold this for 60 seconds.
 - After the test remove the tray from the tester and inspect the seal and measure the minimal seal width of the entire tray seal (not including the width of the anomaly).
 - A proposed accept/reject criteria for seals with anomalies found during the visual inspection could be:
 - If the closure seal opens or delaminates during the test, the tray is rejected and the defect is “critical”
 - If the minimum closure seal width is less than 1/16” even if it did withstand the ND-test conditions, the tray is rejected and the defect is “critical”
 - If the minimum closure seal width is more than 1/16” but less than 1/8” after testing, the defect is “minor”

- If the minimal closure seal is more than 1/8", the anomaly did not effect the performance of the tray and the defect will not be scoreable as a defect.
- Using the above protocol, the tester will generate forces that exceed the forces seen during transportation and the ND test can predict the effect of the defect on the performance of the tray and thus substantiate if a defect should be scored as minor, major, critical or nothing. The accept/reject criteria however needs to be validated in cooperation with the producer and with input from the USDA-PPB, Natick and DSCP contracting.
- It is proposed that a total of 200 trays with visual defects (critical, major and minor), but no open seals, non-continuous seals, cuts, holes and fold-over wrinkles) and spread over at least 5 different products be tested in the ND tester. The test will be performed at CORANET Demo Facility on trays supplied by Industry Partners that either have been sorted out during a 100% post retort inspection process or were identified during the 200 tray end item inspection by either the producer and/or USDA inspection agency. Each tray will be clearly marked for the reason the tray was rejected
- The following data will be collected:
 - Date:
 - Product Name
 - Lot Number
 - Type Defect Found
 - Pass/Fail ND Test
 - Reason Fail ND Test
 - Peel Strength Data

Non Destructive Seal Tester STP#2016

Project Review
May 6, 2005
CAFT/FMT Facility

Agenda

- Objective
- Literature Review
- Seal Strength Data
- Method Development
- Static Compression Test
- Cyclic Test
- Drop Test
- Recommended Test Method
- Demonstration
- Next Steps

Researchers

- CAFT/FMT:
 - Riëks Bruins (Management, Sample Preparation, Protocol Development)
- Industrial Engineering
 - Dr Elsayed (IE coordination)
 - Dr Basily (Design and Fabrication)
 - Hesham Fahmy (Machining)
 - Tom Blyskal (Electrical and Software)
 - Laure Clarue (Drop Test)

Objective

- Develop a non destructive test method for seal strength of polymeric trays that has equal or better performance than Internal Pressure Tester

Integrity versus Strength

- Seal Integrity looks at if anomalies exist within the seal area
- Seal strength looks at seals that are strong enough to withstand abuse (drop test, vibration test)

Literature/Method Review

- Package/Seal Integrity Tests
 - Pressure Differential
 - Visual Inspection
 - Machine Vision
 - Bubble Test
 - Bio Test
 - Electrolytic Test
 - Dye Penetration
 - Various Scanning Techniques

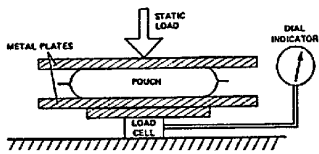
Literature/Method Review

- Seal Strength
 - Inflation Seal Strength
 - Burst Test
 - Creep Test
 - Creep to Fail Test
 - Tensile Test
 - Compression Test
 - Static Method
 - Dynamic Method
 - Squeeze Method

Literature/Method Review

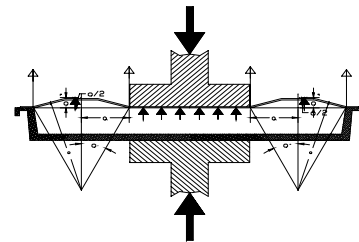
- ASTM F-88, Tensile Test
- ASTM F-1140, Unrestrained Pressure Test
- ASTM F-2054, Restrained Pressure Test
- MIL-PRF-44073-F, IP Test MRE pouches
- MIL-PRF-32004-B, IP Test Poly Tray

Compression Tester for Pouch

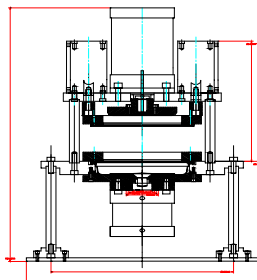


7.5 kg/15mm internal seal length for 15 seconds
MRE: 280 kg or 616 lb

Compression Test for Trays



Compression Tester



Seal Strength Data

- Seal conditions were identified that produced seals of marginal quality
 - 390 F for 2.0 and 3.0 sec
 - Peel Strength Test Data:
 - Smurfit
 - 2.0 sec: Avg: 121 N/inch Min: 68 N/inch
 - 3.0 sec: Avg: 153 N/inch Min: 105 N/inch
 - Japanese
 - 2.0 sec: Avg: 99 N/inch Min: 71 N/inch
 - 3.0 sec: Avg: 131 N/inch Min: 88 N/inch

Static Compression Test

- All samples from the 2.0 sec & 3.0 sec lots passed the Internal Pressure test
- Static compression test conditions were developed that have high fail rate for the 2.0 sec lot and high pass rate for the 3.0 sec lot
- Trays that failed static compression test, failed due to seal sections that were "non fusion"
- Hence, static compression test conditions are better than IP test method to detect non fusion seals

Static Compression Test

- Seals with width of more than 1/8" did pass one or more subsequent compression test.
- Seals with width less than 1/8" did on occasion fail in subsequent compression test
- Hence trays with minimum seal width less than 1/8" should not be put back into production lot and seals with 1/8" or more can be put back into the lot

Cyclic Test

- The hypothesis is that cyclic testing will fail a marginal weak seal in a shorter time due to the flexing of the film near the seal area could not be proven.
- Hence cyclic testing was not added as a test protocol

Drop Test

- Trays with marginal seals were packed and dropped according to Mil specs and tested with static compression test
- Proposed static compression test protocol failed trays that had passed the drop test and is thus more severe than drop test
- Hence passing the static compression test assures that the trays will pass the drop test

Recommended Test Protocol

- Measure Min Seal width before test, if seal width less than 1/8" reject tray
- Compress Tray at 50 psig (internal pressure ~ 20 psig) and hold for 60 seconds. Compression Force ~1,400 lbf
- Tray fails the test if seal fails during test or minimum seal width after test is less than 1/16"
- Tested Tray with min. seal width of 1/8" or more can be put back into the lot. Trays that passed the test but min seal width < 1/8", can not be added back to production lot

Demonstration

Next Steps

■ Plant Trials

1. Inspection of questionable seals from the 200 tray visual inspection.
 - Minimum Seal Width > 1/16", pass tray
 - Inspect Lid stock for cracks/pin-holes
 - If Seal Tester does not increase cracks & pin-holes in lid stock, add trays with seals > 1/8" back to lot
2. Inspect Finished Product Lots
 - Minimum Seal Width > 1/8", pass tray and add back
 - Minimum Seal Width > 1/16" but <1/8", pass tray but do not add tray back to lot

Non Destructive Seal Tester STP#2016

Project Review
May 31, 2006
CAFT/FMT Facility

Agenda

- Objective
- Method Development
- Static Compression Test
- Test Protocol
- Validation Test Results
- Demonstration
- Next Steps

Researchers

- CAFT/FMT:
 - Rieks Bruins (Management, Sample Preparation, Protocol Development)
- Industrial Engineering
 - Dr Elsayed (IE coordination)
 - Dr Basily (Design and Fabrication)
 - Hesham Fahmy (Machining)
 - Tom Blyskal (Electrical and Software)
 - Laure Clarue (Drop Test)

Objective

- Develop and validate a non destructive test method for seal strength of polymeric trays that has equal or better performance than Internal Pressure Tester.
- Validate if non destructive seal tester can quantify the effect of visual seal defects on overall seal strength.

Literature/Method Review

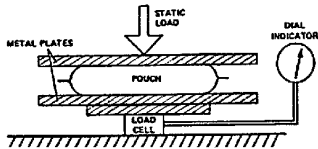
- Seal Strength
 - Inflation Seal Strength
 - Burst Test
 - Creep Test
 - Creep to Fail Test
 - Tensile Test
 - Compression Test
 - Static Method
 - Dynamic Method
 - Squeeze Method

Internal Pressure Data vs Seal Peel Force Data

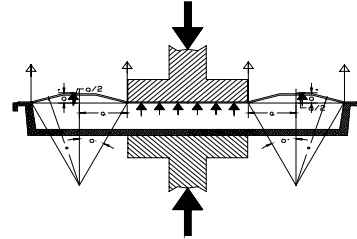
- Yam (1993): $S = p \cdot R$ (S=Seal Peel Force, p=internal pressure, R= Radius film)
- MRE Internal Pressure: 5.0 lbf/inch
 - 1/8" gap between the two restrainer plates (R=1/4")
 - 20 psig internal pressure
- Poly Tray Internal Pressure: 2.5 lbf/inch
 - 1/8" gap between flange and restrainer plate (R=1/8")
 - 20 psig internal pressure



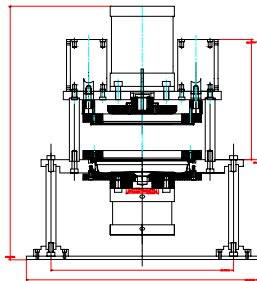
Compression Tester for Pouch



Compression Test for Trays



Compression Tester



Development of Marginal Seal Quality

- Peel Strength Data Production Trays (410 F for 3.5 sec)
 - Avg: 41 lbf/inch Min: 37 lbf/inch
- Heat Seal conditions were developed that produced seals of marginal quality: 390 F for 2.0 sec & 3.0 sec.
- Trays sealed under 390 F for 2 sec had tacky/non fusion seal sections
- Trays sealed under 390 F for 3 sec were fusion seals.
- Peel Strength Test Data:
 - Smurfit
 - 2.0 sec: Avg: 26 lbf/inch Min: 15 lbf/inch
 - 3.0 sec: Avg: 34 lbf/inch Min: 23 lbf/inch
 - Japanese
 - 2.0 sec: Avg: 22 lbf/inch Min: 16 lbf/inch
 - 3.0 sec: Avg: 29 lbf/inch Min: 19 lbf/inch

Condition for Static Compression Test ?

- Both the 2 sec and 3 sec seal samples passed the IP test
- Static compression test conditions 1400 lbf for 60 seconds resulted in high fail rate for the 2.0 sec lot and high pass rate for the 3.0 sec lot
- Trays that failed static compression test, failed due to seal sections that were "non fusion"
- Hence, static compression test conditions are better than IP test method to detect non fusion seals

Compression Test vs Drop Test

- Trays with marginal seals were packed and dropped according to Mil specs and passed
- Proposed static compression test protocol failed trays that had passed the drop test and is thus more severe than drop test
- Hence passing the static compression test should assure that the trays will pass the drop test

Is the Static Compression Test None Destructive?

- Seals with width of more than 1/8" did pass one or more subsequent compression test.
- Seals with width less than 1/8" did on occasion fail in subsequent compression test
- Hence trays with minimum seal width less than 1/8" should not be put back into production lot and seals with 1/8" or more can be put back into the lot

Recommended ND Test Protocol for Lot Acceptance

- Measure Min Seal width before test, if seal width less than 1/8", select other tray
- Compress Tray between two plates, the top plate outer perimeter is 1" within the flange of the tray. The bottom plate is shaped according to the oval indentation of the bottom of the tray. Apply a Compression Force of 1,400 lbf on the tray and hold for 60 seconds (~20 psig inside tray)
- Inspect the tray seal after the test. The tray fails the test if the minimum seal width is less than 1/16", otherwise the tray passes the test.
- Tested Tray with min. seal width of 1/8" or more can be put back into the lot. Trays that passed the test but min seal width < 1/8", can not be added back to production lot

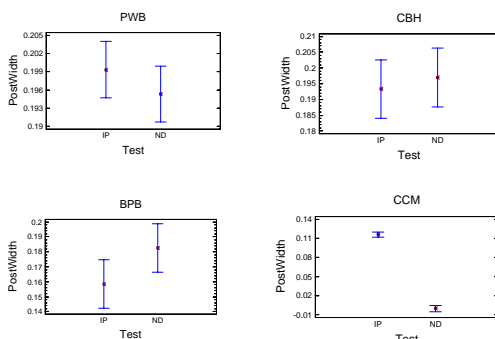
Validation Testing

- Finished Product Trays obtained from Gov' Depot
 - Chicken Chow Mein (CCM)
 - Potato with Bacon (PWB)
 - Beef Patties (BPB)
 - Corn Beef Hash (CBH)
- Each Tray tested via IP and ND protocol
- Minimal Seal Width determined before and after each test
- Data analyzed for statistical significance

Test Performed

Test Sequence	IP	ND	Total
IP-ND	70	70	140
ND-IP	55	65	120
Total	125	135	260

Seal Width



Conclusion

- The ND test failed none fusion seals that passed the IP test and thus a higher seal quality standard is required to pass the ND test
- Seal width of trays with good quality seals were statistical similar after the IP and ND test. Seal width of trays with marginal quality seals are significant less after the ND test than after the IP test.
- The ND tester is better in detecting weak/non fusion seals than the current IP tester.

Recommended Protocol for Evaluating Seal Defects

- Test Tray with Visual Defect in ND tester (1400 lbf/60 sec). Examine seal after Test is completed
- If the closure seal opens during the test, the tray is rejected and the defect is "critical"
- If the minimum closure seal width is less than 1/16" after test, the tray is rejected and the defect is "critical"
- If the minimum closure seal width is more than 1/16" but less than 1/8" after testing, the defect is "minor"
- If the minimal closure seal is more than 1/8", the defect did not effect the performance of the tray and the defect will not be scoreable.

Status Quantification of Visual Defects (Daytona Meeting)

- 62 trays for testing spread over 6 products
- 32 trays had visual defect, impression and/or seal wrinkles
- Results:

- 28 not scorable, seal width $>1/8"$ (87.5%)
- 3 minor: seal width $>1/16$, $<1/8"$ (9.4%)
- 1 critical: seal width $<1/16"$ (0.3%)

Note: seal creep did not occur in area where visual defect was observed (Tray 9C, Tray 10A and Tray 10C)

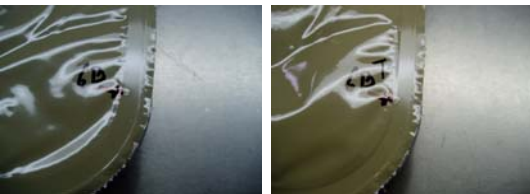
Trays with No Visual Defects in Seal

- Total Tested: 30 trays
- Results:
 - 28 passed
 - 2 failed (seal burst)

Observations

- Visual Defects did not correlate to Seal Failure
- Seal Creep and Seal Failure was observed in seals that had no Visual Defects.

Tray 6B, Visual Defect but resulting seal $> 1/8"$, hence not scorable



Tray 9C: Visual Defect, resulting seal $>1/8"$, hence none scorable, but



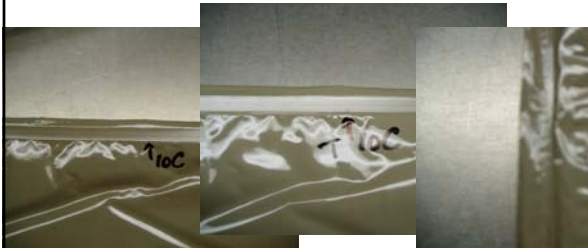
Tray 9C:Seal creep occurred in area without visual defects. Resulting Seal $>1/16''$, $<1/8''$ hence defect is minor



Tray 10A: Visual defect did not cause seal creep, but seal creep occurred in different area. Resulting Seal $>1/16''$, $<1/8''$, hence defect is minor



Tray 10C: Visual defect did not cause seal creep, but seal creep occurred in different area. Resulting Seal $<1/16''$, hence defect is critical



Next Steps Quantification Visual Seal Defects

- No additional samples received after Daytona meeting
- Obtain additional samples with seal defects and complete analysis of impact of defect on overall seal strength

Demonstration

Next Steps

- Evaluate Test Protocols
- Visual Defect Evaluation at Rutgers
- Use Tester in Plant for:
 - Seal Anomalies/Defects
 - Finished Product Lot Acceptance